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Memoirs of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. IX. NO. 2.

SELECTIONS

FROM

EMBRYOLOGICAL MONOGRAPHS.

COMPILED BY

ALEXANDER AGASSIZ,
WALTER FAXON, AND E. L. MARK.

II.—ECHINODERMATA.

BY ALEXANDER AGASSIZ.

WITH FIFTEEN PLATES.

CAMBRIDGE:
Printed for the Museum.
JULY, 1883.

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NOTICE.

The Bibliography of the Echinodermata, by A. Agassiz, to accompany the second part of the "Selections from Embryological Monographs," has been published as No. 2 of Vol. X. of the Bulletin of the Museum.

The Bibliography of the First Part, the Crustacea, by Walter Faxon, forms No. 6 of Vol. IX. of the Bulletin of the Museum. The Plates have been published as No. 1 of Vol. IX. of the Memoirs of the Museum.

Other Parts of the Bibliography and of the Plates are in preparation, — Protozoa, Acalephs, Polyps, Fishes, and Reptiles.

ALEXANDER AGASSIZ.

Museum of Comparative Zoölogy,
Cambridge, Mass., U. S. A.

July, 1883.

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EMBRYOLOGICAL MONOGRAPHS.

PLATE I.

Development of Crinoidea (*Comatula*). *Figures from* C. Wyville Thomson *and* Alexander Goette.

1–9. *Comatula rosacea.* From C. Wyville Thomson, On the Embryogeny of Antedon rosaceus Linck (Comatula rosacea of Lamark), 1863. Trans. R. S. London, CLV., 1865, Pls. XXIII.–XXVII.

10–26. *Comatula mediterranea.* From Alexander Goette, Vergleichende Entwickelungsgeschichte der Comatula mediterranea, 1876, Pls. XXXV., XXXVI. Archiv für Microskop. Anat., XII.

27–35. *Comatula rosacea.* From C. Wyville Thomson, On the Embryogeny of Antedon rosaceus, quoted above.

1–9. *Comatula rosacea.* From C. Wyville Thomson.

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10–26. *Comatula mediterranea.* From A. Goette.

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a f. Anus.
b b. Longitudinal axis of the gastrula.
c. Gastrula mouth.
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d'. Œsophagus.
f. Base of the stem of the Comatula larva.
f'. Plate of base of stem.
l p. Left peritoneal sac (oral body cavity).
l p'. Oral chamber.
m. Mouth.
m d. Mesoderm.
m t. Mesentery.
o b. Outer skin.
o b'. Yellow cells of the same.
o t. Oral funnel.
p. Perisome.
r. Circular canal.
r p. Right peritoneal sac (aboral body cavity.)
r p'. Continuation of the same into the stem.
s t. Stem of the young Comatula larva.
s t'. Skeleton of the stem.
t t. Contractile tentacle.
t t'. Non-contractile (rigid) tentacles.
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v s'. Its continuation between the intestine and the water-system.
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11. Median section through a somewhat older larva.
12–15. Frontal sections of successively older larvæ, seen from the dorsal side.
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17, 18. Sagittal sections; the median section is indicated in outline.
19. Median sections of a somewhat older larva.
20. Frontal section, seen from the ventral side; the perisome begins to be intimately united with the outer skin and the parietal plate.

21. A larva at the time when the skeleton begins to form; the diagonally transverse dark stripe running across the digestive cavity indicates the position of the mesentery.
22, 23. Sagittal section of a young embryo with a stem.
24. Frontal section of a similar larva; the two layers of the rudimentary ring canal and tentacles begin to separate.
25. Median section of a much older embryo, with a comparatively longer stem. *z*, hood of the oral anterior chamber.
26. Transverse section of a larva perhaps slightly older, anterior plane.

27–35. *Comatula rosacea*. From C. Wyville Thomson.

27. Dorsal view of a pseudembryo about in the stage of fig. 9.
28. Lateral view of a pseudembryo somewhat older than the preceding figure; the ciliated bands are disappearing.
29. The pseudembryo is losing its special organs of assimilation and locomotion, and is passing into the Pentacrinoid stage.
30. The youngest Pentacrinoid stage.
31. Pentacrinoid larva immediately after the complete separation of the oral valves, expanded.
32. A portion of the oral disk of the same stage seen from above, in a state of complete expansion; *a*, patent oral aperture bounded by a ring of contractile tissue, and showing yellow, richly ciliated granular folds, arranged somewhat spirally on the walls of the digestive cavity; *b*, central ring of the radial vascular system; *c*, rigid non-extensile tentacles in immediate connection with the vascular ring, ten in number, and laid up in a state of complete expansion in pairs against the inner surface of the oral valves, *f*: *d*, the first pair of extensile radial tentacles; *e*, azygous radial extensile tentacle leading out of the growing arm to its bifurcation, and giving off pairs of tentacles of the same series from its base.
33. Pentacrinoid in the same stage as fig. 31, the cup closed.
34. Pentacrinoid larva immediately before the expansion of the ventral disk; *a*, centrodorsal plate; *b*, series of basal plates; *c*, first radial plates; *d*, second radial joint; *e*, third radial; *f*, first brachial joint; *g*, anal plate; *h*, stem joint; *k*, cribriform plate supporting the disk of attachment; *l*, granular visceral mass; *m*, cæcal process passing from the stomach towards the papilla which indicates the position subsequently occupied by the anal tube; *n*, oral valve and plate.
35. Another Pentacrinoid larva in a somewhat earlier stage than the preceding, expanded, and showing the arrangement of the non-extensile tentacles in connection with the oral vascular ring.

PLATE 11.

Development of Crinoidea (*Comatula*), *continued. Figures from* William B. Carpenter, George J. Allman, *and* Hubert Ludwig.

1–17. *Comatula rosacea*, continued. From William B. Carpenter, Researches on the Structure, Physiology, and Development of Antedon (Comatula Lamk.) rosaceus, Part I., 1866. Trans. R. S. London, CLVI., 1866, Pls. XXXIX.–XLII.

a.	Anal plate.	*c d.*	Centrodorsal plate.
b b.	Basals.	*o o.*	Oral plates.
b r.	Brachials.	r^1, r^2, r^3.	First, second, and third radials.
c.	Cirri.	*v.*	Vent.
c'.	Central pore.		

1. Greatly enlarged view of a Pentacrinoid larva, in a stage nearly corresponding with that of fig. 7, the nearest ray having been removed so as to bring into view the oral apparatus: *c d*, centrodorsal plate bearing two cirri, one rudimentary, the other, *c*, in an advanced stage of development; r^1, r^2, r^3, first, second, and third radials; *o o*, orals, now completely separated from the radials by the intervention of a membranous perisome.
2. Calyx of the same specimen, seen from the other side, showing the centrodorsal plate bearing two cirri, one rudimentary, the other, *c*, still retaining its rudimentary form; the first, second, and third radials, $r^1\ r^1$, $r^2\ r^2$, $r^3\ r^3$, and the anal plate, *a*, are now lifted out from between the first radials by the development of the prominent vent, *v*, to which it is attached.

3, 4, 5, 6, 7. Pentacrinoidal larvæ in different stages. Figs. 4–7 are the successive stages preceding the fully developed Pentacrinoid stage, fig. 3.

3. Shows the Pentacrinoid ready to assume its free condition, two rows of dorsal cirri being now completed, the arms being considerably elongated by the addition of new segments, and several pairs of pinnules being formed at their extremities.
4. Shows the basal, *b b*, the circlet of first radials, $r^1\ r^1$, already complete, the rudimentary second and third radials supported by this and the circlet of orals, *o o*, alternating with these and resting on the first radials.
5. Shows the incipient development of the arms from the extremities of the third radials, the relative position of the other parts being but little changed, and the dorsal cirri not having yet made their appearance. See fig. 10 for a representation of the skeleton in this stage on a larger scale.
6. Showing the further development of the arms, the incipient opening out of the calyx occasioned by the increased development of the first radials, and the first appearance of the dorsal cirri.
7. Showing the first appearance of the pinnules at the extremities of the arms, the further opening out of the calyx, bringing the vent to view, and the formation of the first whorl of dorsal cirri.
8. Skeleton of an early Pentacrinoid larva, from a dried specimen, showing the mode in which the calyx can be (in that stage) completely closed in by the folding together of the orals, *o o*.
9. Skeleton of the Pentacrinoid larva of fig. 3, showing two rudimentary segments of the stem, the incipient development of the dorsal cirri, the basals, *b b*, the first, second, and third radials, and the anal, *a*, now being lifted up from between the first radials.
10. Skeleton of Pentacrinoid at the time of the first development of the arms, and before the first appearance of the dorsal cirri; *b b*, basals; $r^1\ r^1$, first radials; *a*, anal; $r^2\ r^2$, second radials; *o o*, orals; $r^3\ r^3$, third radials.
11. Skeleton of the calyx of a Pentacrinoid nearly ripe for detachment, as seen from its internal or ventral aspect, the centrodorsal plate having been removed; *b b*, basals; $r^1\ r^1$, first radials.
12. The same as seen from its external or dorsal aspect; *c*, central pore for the passage of the sarcodic axis through the centrodorsal plate; *bb*, basals; $r^1\ r^1$, first radials; r^2, second radials; r^3, third or axillary radials; *b r*, brachials; *a*, anal.

13. Incipient rosette formed by the coalescence of the five altered basals in a young Antedon.
14. Skeleton of base of calyx of young Antedon, seen from its internal or ventral side ; showing the five basals (*b*) altered by endogenous growth in preparation for the formation of the rosette.
15. Skeleton of base of calyx of young Antedon seen from its dorsal aspect, the centrodorsal plate having been removed ; showing that the central space round *b*, on the under side, has been enlarged by the resorption of a part of the original basals, though it is still contracted, near the cavity of the calyx, by the secondary endogenous growth, with the same system of axial canals as are figured in the subsequent figure (fig. 16).
16. The same as fig. 15, seen from the ventral aspect ; showing the five basals grouped around *b*, and traversed by canals for the radiating cords of the sarcodic axis, of which a trunk enters each basal from the central space, and then subdivides into two branches, that pass into the two radials between which the salient angle of the basal projects ; thus each first radial receives cords from two basals, and these are lodged in two canals which coalesce into one towards its distal border, each of them having first become connected by a lateral branch with the like canal in its contiguous first radial ; <–*a*–> shows the position of the anal.
17. Calyx of young Antedon just detached, seen from its dorsal side, showing five cirri of the mature type and five of the rudimentary type, the radial and brachial plates, and the extension of the visceral disk as far as the third radial.

18–21. *Comatula rosacea*, continued. From George J. Allman, On a Prebrachial Stage in the Development of Comatula and its Importance in Relation to certain Aberrant Forms of Extinct Crinoids (1863), Pl. 13. Trans. R. S. Edinburgh, XXIII. Part II., 1864.

18. The animal with its roof-plates fully expanded and the cirri extended from between their edges.
19. The same in the act of expansion.
20. The same with the cirri entirely withdrawn, and the roof-plates closed.
21. Outline of the body looking down upon it from the vertex.

22, 23. *Antedon Larva.* From H. Ludwig, Ueber den primären Steinkanal der Crinoiden, nebst vergleichenden anatomischen Bemerkungen über die Echinodermen überhaupt, 1880, Pl. XII. Zeits. f. Wiss. Zool., XXXIV. Morphol. Studien an Echinodermen, II. Heft 1.

22. Optical longitudinal section of an Antedon larva. M, mouth ; D′, œsophagus ; D″, stomach ; L L′, body cavity ; H, position of the so-called heart ; W, water-system ring ; S T, stone canal ; T, tentacle ; K, reddish-brown body ; F, axial cord of the stem.
23. Diagrammatic sketch of an Antedon larva. D‴, intestine ; A, anus ; P, pore in calyx ; T, T′, T″, tentacles ; other letters as in fig. 22.

PLATE III.

Development of Ophiuroidea. *Figures from* Elias Metschnikoff, Hubert Ludwig, Alexander Agassiz, T. H. Stewart, Max Schultze, *and* August Krohn.

(1–20, 26–33, *Viviparous Ophiurans.*)

1–14. *Amphiura squamata.* From E. Metschnikoff, Studien über die Entwickelung der Echinodermen und Nemertinen. Mém. de l'Acad. Imp. des Scien. de St. Pétersbourg, VII^e^ Série, XIV. No. 8, Pls. III. B, IV., 1869.

b l.	Blastoderm.	*o.*	Mouth.
c.	Cutis.	*o c.*	Œsophagus.
c c.	Provisional limestone rods; probably the homologue of the Pluteus rods.	*p a.*	Dorsal pore of the water-system (madreporite).
		p l.	Remnant of rudimentary Pluteus.
c p l.	The bilateral embryonic skeleton.	*t.*	Tentacles.
c s.	Segmental cavity.	*v.*	Rudimentary water-system.
d^1.	Left lateral disk.	*v a.*	Water-system.
d^2.	Right lateral disk.	*v t.*	First trace of digestive cavity.
e p.	Epidermis.	*v v.*	Lobed water-system.
m e.	Thin outer membrane surrounding blastoderm.	*v p, v r.*	Circular canal.
m v.	Thick inner membrane of same.		

1. Egg, surrounded by its two membranes (*m e*, *m v*) with the blastoderm (*b l*).
2. The same in profile: the outer egg membrane is not figured.
3. Somewhat more advanced stage, showing, in addition to the blastoderm, the first indication of the digestive cavity (*v t*) and of the large cells of the cutis (*c*).
4. Elongated embryo still protected by the inner egg membrane (*m v*). The deposition of the provisional limestone rods has commenced (*c c*). On each side of the future œsophagus are placed the rudiments of the water-system (*v*).
5. Somewhat older embryo, with longer limestone rods (*c p l*), seen in profile.
6. Still older embryo, seen from the dorsal side, showing the greatly enlarged water-system (*v a*) and its two lateral disks (d^1, d^2).
7. Somewhat older embryo, also seen from the dorsal side, showing the five lobes of the water-system (*v a*).
8. Older stage, remarkable for the great development of the lateral disks (d^1, d^2), the change in the position of the digestive cavity and œsophagus, the great increase in the size of the lobes of the water-system (*v v*), and the formation of a dorsal pore (*p a*), the future madreporic body.
9. Somewhat older embryo, showing the horseshoe-shaped water-system, each primary fold of which (*v v*) has subdivided into four secondary lobes.
10. Embryo seen in profile. The œsophagus is already surrounded by the water-system; each fold of the water-system has subdivided into five smaller ones. The stone canal is most distinct.
11. An embryo about in the stage of fig. 10, seen from the dorsal side: the provisional limestone skeleton is already disappearing.
12. The water-system of the same embryo: *v v*, the blind sacs (tentacles) of the water-system; *v r*, the circular canal; *p a*, the madreporite.
13. The embryo in a stage immediately after passing from the bilateral to the pentagonal form, seen from the actinal side; the peculiar arrangement of the tentacles (*t*) and the formation of the mouth skeleton are specially to be noticed in this stage.
14. Somewhat more advanced than the preceding stage, seen from the dorsal side, showing the six reticulated plates of the abactinal surface, as well as the stem (*p l*), first described by Krohn and Schultze, forming a temporary connection with the ovary. This becomes atrophied in still older stages.

14′–19. *Amphiura squamata.* From Hubert Ludwig, Zur Entwickelungsgeschicte des Ophiurenskelettes, 1882 (Morphol. Studien, II., Heft 2). Zeits. f. Wiss. Zool., XXXVI., Pl. XI.

A_1, A_2. First and second ambulaeral plates.
$A\,d_1$, $A\,d_2$, $A\,d_3$, etc. First, second, third, etc. adambulacral plates.
C. Dorsocentral plate.
m. Madreporic plate.
O. Oral plates (mouth shields).
R. Primary radials.
R a. Radials of the young ophiuran.
T. Terminal plates.
T o. Torus angularis.
t. Teeth.
V V′. Ventral plates.
x. Remnant of embryonic skeleton.

14′. Young Amphiura, seen from the dorsal side. The composition of the plates, of *y*-shaped rods, is still plainly visible.

15. Somewhat older stage, seen from the actinal side. *V*, oldest ventral plate; *V′*, very young ventral plate; *t*, rudimentary teeth.

16. Somewhat older than fig. 14′, but younger than fig. 15, seen from the dorsal side.

17. Somewhat older than the stage corresponding to fig. 19, seen from the dorsal side, showing the arrangement of the intermediate plates formed between the central and the primary radials.

18. Somewhat older than the stage of fig. 17, seen from the dorsal side; the intermediate plates have greatly increased in size and number.

18′. Shows the arrangement of the plates of the actinal side in a stage slightly older than fig. 17.

19. Stage corresponding to fig. 15, seen from the dorsal side; intermediate plates begin to appear between the central plates and the primary radials.

20–23. *Ophiopholis* (?) and *Amphiura* (?). From Alexander Agassiz, On the Embryology of Echinoderms. Mem. Am. Acad., IX., figs. 29, 31–33, 1864.

20. *Ophiopholis bellis?* From a drawing made under the direction of L. Agassiz in 1849. Abactinal view of a young Ophiopholis to show the arrangement of the plates of the disk.

21–23. *Amphiura?*

21. A full-grown Pluteus, in which the water-tubes, *w*, *w′*, are plainly seen. *d*, digestive cavity; *m*, mouth; *a*, anus; *t*, rudimentary tentacular lobes of the water-system; *v′*, anal, and *v*, oral vibratile cord; c'–c^4, arms of the Pluteus.

22. Older stage, seen from the abactinal side, in which the arms of the Pluteus (c''–c^4) are almost entirely resorbed; the two long arms c' are still intact, they are omitted for want of space. *r*, abactinal region; *y*, rudimentary terminal plate; *y′*, adambulacral plate; r^4, junction of limestone rods of the long arms c'.

23. The same, seen from the actinal side; lettering as above: *s*, actinal region; *t*, *t′*, tentacular loops.

24, 25. *Ophiocoma rosula.* From T. H. Stewart, On the Young State of Ophiocoma rosula, and on the Form and Development of the Spines of this Species. Ann. & Mag. Nat. Hist., XVIII., 1856, Pl. XV.

24. Young Ophiocoma seen from the abactinal side.

25. Actinal view of central portion of the disk.

26–31. *Amphiura squamata.* From Max Schultze, Ueber die Entwickelung von Ophiolepis squamata, einer lebendiggebährenden Ophiure. Archiv. f. Anat. Phys. u. Wiss. Med., 1852, Pl. I.

26. Ovarian eggs of *Amphiura squamata.*

27. Young embryo with rudimentary provisional limestone rods.

28. Somewhat older than fig. 27, the embryonic limestone rods are arranged symmetrically.

29. Older embryo. In addition to the provisional limestone rods, *a*, we have also the radials, *b*, developed; and the first trace of the terminal plates, *c*.

30. The embryo has assumed a pentagonal outline; of the provisional limestone rods we find only the remnants at *a*; lettering as before; the plates of the abactinal side are seen through from the ventral side under the rudimentary actinal plates.

31. Portion of a young Amphiura measuring $\frac{1}{4}'''$ in diameter, seen from the actinal side: *a*, interbrachial dorsal plates; *b c*, actinal plates adjoining actinostome; *d d*, interbrachial plates of the actinal side; *e e*, spoon-shaped brachial plates; *f*, terminal plates; *g*, *g*, tentacles; *h*, teeth.

32, 33. *Viviparous Ophiuran.* From August Krohn, Ueber einen neuen Entwickelungsmodus der Ophiuren. Archiv. f. Anat. Phys. u. Wiss. Med., 1857, Pl. XIV. B.

32. Actinal view of ophiuran embryo; *a*, pentagonal disk of young ophiuran; *b*, central cavity, the future mouth; *c*, tentacles; *d*, tentacles of actinostome; *e*, remnant of rudimentary Pluteus.

33. Young ophiuran of same embryo; *a*, dorsal plates; *b*, arm plates; *c*, terminal plate; *d*, spines of the actinal side projecting beyond the disk.

PLATE IV.

Development of Ophiuroidea, *continued. Figures from* Nicolas Christo Apostolidès *and* Johannes Müller.

1–13. *Ophiothrix versicolor.* From N. C. Apostolidès, Anatomie et Développement des Ophiures. Archives de Zool. Exp et Gén., X., Pl. XI., 1881.

1. Egg. *m*, outer envelope ; *y*, yolk ; *v*, germinative vesicle ; *n*, nucleus.
2, 3, 4, 5. Different stages of segmentation.
6. Blastosphere.
7. Blastosphere. *e*, ectoderm cells.
8. Older than fig. 7. *e*, ectoderm; *y*, yolk cells.
9. Older stage ; lettering as before. First appearance of the limestone rods of the Pluteus.
10. Still older stage ; *r*, the limestone rods of the Pluteus have increased in size.
11. Slightly older ; the digestive cavity, *d*, is outlined.
12. The embryo assumes somewhat the Pluteus outline.
13. Young Pluteus seen from the dorsal side. *p*, general cavity ; *f*, limestone rods ; *a*, anal region of the digestive cavity.

14–26. *Ophiothrix fragilis.* From J. Müller, Ueber die Ophiurenlarven des Adriatischen Meeres, Berlin (Pt. 5), (1851,) Pls. VI., VII., VIII. Abhand. d. K. Akad. d. Wiss., Berlin, 1852.

14–17. Younger stages of the Pluteus. *m*, mouth ; *d*, digestive cavity.
18. Pluteus at a stage in which all the arms are developed, although the two long arms have by no means reached their full length (see fig. 19). *m*, mouth ; *o*, œsophagus; *d*, digestive cavity ; *i*, intestine ; *w*, *w'*, lateral disks of water-tubes ; *t*, lobed water-system.
19. Pluteus of same, in which the two long arms have reached their full length : lettering as in fig. 18.
20. The long arms of the Pluteus alone remain (extremities omitted) ; the others have been mostly resorbed ; the young ophiuran has assumed a pentagonal outline ; the plates of the abactinal system, the terminal arm plates, and the interbrachial plates, are represented by *y*-shaped rods. t', terminal lobes (tentacles) ; t^1, actinal lobes ; t^2, second pair of lobes.
21. Pentagonal Ophiothrix, seen from the dorsal side : the teeth are seen through the disk.
22. The same as fig. 21, seen from the actinal side, the arms folded towards the actinal opening, showing also the hooks, the teeth, and the true mouth in the depth of the central star-shaped mouth.
23. Slightly older, seen in profile : the long arms of figs. 20–23 are still of full length.
24. A young Ophiothrix after the loss of the two long arms, seen from the dorsal side.
25. Somewhat older than stage of fig. 23, seen from the actinal side. t', t^1, t^2, t^3, terminal, actinal, and second and third pairs of tentacles.
26. Young Ophiothrix, seen from the abactinal side, with two arm-joints. All traces of the Pluteus have disappeared.

27–34. *Pluteus bimaculatus.* From J. Müller, Ueber die Ophiurenlarven des Adriatischen Meeres, Pls. IV., V., quoted above.

27. Shows the young ophiuran at the time when the arms of the Pluteus begin to be resorbed and the tentacular lobes are arranged in a horseshoe shape round the actinostome ; lettering as in fig. 25.
28. Somewhat older stage, seen from the actinal side ; the young ophiuran has assumed a pentagonal outline; the terminal arm plates and the interbrachial plates are well developed ; the actinal tentacles are bent in towards the centre of the actinostome.
29. Still older stage, also seen from the actinal side, with three pairs of tentacles.
30. Somewhat older stage, seen from the abactinal side ; the plates of the disk, the centrodorsal, radials, and intermediates, are well developed.

31. Older ophiuran seen from the actinal side; t', t^1, t^2, t^3, terminal, and first, second, and third pairs of tentacles.
32. Free ophiuran without Plutean appendages, fished up from the surface. $\frac{6}{10}'''$ in diameter. Seen from the dorsal side.

    The stages 27–31 all have the two long arms intact; the other shorter arms are in different stages of resorption; see figs. 27, 28, 30. The long arms are not figured for want of space.
33. A single arm of fig. 32, from the abactinal side.
34. The central part of the disk with a portion of the arm of the same from the actinal side, showing the teeth and the mouth papillæ. Neither Müller nor Metschnikoff was able to determine the ophiuran which is developed from *Pluteus bimaculatus*. Müller considered it at first to be *Ophiolepis squamata*.

PLATE V.

Development of Asteroidea. *Figures from* Wilhelm Busch *and* Hubert Ludwig.

1 – 4. *Echinaster sepositus.* From W. Busch, Beobachtungen über Anatomie und Entwickelung einiger Wirbellosen Seethiere. Berlin, 1851, Pl. XII.

1. Young pelagic embryo : *a*, body ; *b b*, so-called brachiolarian appendages.
2. The same embryo somewhat more advanced : *a*, the body where the future Starfish is developed ; *b b*, so-called brachiolarian appendages ; *c*, commencement of a third pair.
3. The young starfish has assumed a pentagonal outline ; the tentacles (*b*) of the disk are clearly indicated, and the brachiolarian appendages have taken their maximum development on each side of the axis *a*.
4. The most advanced stage of the young Echinaster observed by Krohn. The brachiolarian appendages are reduced by resorption to mere rudiments, *a* ; *b*, older pair of tentacles ; *d*, odd terminal tentacles ; *e*, youngest pairs of tentacles ; *f*, actinal ambulacral furrow.

5 – 49. *Asterina gibbosa.* From H. Ludwig, Morphologische Studien an Echinodermen, II., 2 Heft, 1882. Zeits. f. Wiss. Zool., XXXVII., Pls. I. – VI.

A_1. First ambulacral plate.
A_2. Second ambulacral plate.
Bl. Blood system.
C. Dorsocentral plate.
D. Digestive cavity.
E C. Enterocœlum.
Ect. Ectoderm.
E h. Egg membrane.
Ent. Entoderm.
G m. Gastrula mouth.
H C. Hydrocœlum.
JR_1, JR_2, JR_3, JR_4, JR_5. First to fifth interradial.
l El. Left enterocœlum pouch.
L m. Larval mouth.
L s. Larval œsophagus.
M. Mesentery.
M s. Mesoderm.
P. Dorsal pore.
r El. Right enterocœlum pouch.
T_1, T_2, T_3, T_4, T_5. First to fifth terminal plates.
1, 2, 3, 4, 5, denote the Hydrocœlum lobes and ambulacral arm lobes.
I, II, III, IV, V, denote the antiambulacral arm lobes; *O* denotes the upper side of the embryo or larva ; *U*, the lower ; *H*, the posterior, and *V*, the anterior extremity ; *L*, left ; *R*, right; *V L*, in front to the left ; *H U*, behind and below.

5 – 10. Stages of segmentation of the first day.
5. Three spheres of segmentation are shown. I, I, are formed from the division of the upper of the two spheres ; II, the lower sphere ; this is originally somewhat larger than the upper sphere.
6. The lower sphere, II, is now also divided into two, II_1 . . . .
7. The same as fig. 6, so turned as to show the two spheres I_1 . . . .
8. The stage with four spheres somewhat older than the preceding figures.
9. A stage with eight spheres ; I_2 and II_2, the two spheres resulting from the division of the spheres I and II of the stage of fig. 8.
10. Stage with sixteen spheres, which have resulted from the subdivision of the cells I_2 into I_3, and of the cells II_2 into II_3.
11. Section through a blastula composed of 32 spheres.
12. Longitudinal section of a gastrula on the second day. *G m*, the gastrula mouth.
13. The same stage, looking into the gastrula mouth.
14. Longitudinal section of an older gastrula, with a decidedly narrower opening, *G m*.
15, 16, 17. Posterior, anterior, and right view of an embryo just escaped from the egg, fourth day.
18. Longitudinal section of a gastrula somewhat older than fig. 14 ; the gastrula mouth is approaching the lower pole : *a*, the point at which the diverticula of the gastrula digestive cavity begin to be formed.

19. Gastrula three days old. The diverticulum of the gastrula cavity begins to be formed on the left and right sides. *a* shows the left diverticulum.
20. Longitudinal section of a gastrula soon after its escape from the egg ; the left and right enterocœlum pouches are indicated.
21. The same stage as fig. 20, seen from the left side : *L m*, the invagination of the ectoderm which eventually forms the larval mouth.
22. The same stage as fig. 20, seen from the right side.
23. Embryo at the beginning of the fifth day, seen from the left. *a*, point of separation of the gastrula cavity and the enterocœlum ; *b* indicates the position of the gastrula mouth, *Gm*, which has now disappeared.
24. Transverse section of an embryo in the stage of fig. 23.
25. Longitudinal section of an embryo at the end of the fourth day ; in which the gastrula cavity *a* is still in communication with the enterocœlum.
26. Longitudinal section of an embryo at the end of the fifth day: the communication between the gastrula cavity and the enterocœlum has become completely shut off at *a*.
27. Larva of the seventh day, seen from the left side ; the intestine, of which the position is merely indicated, has been removed, to show the mesentery, *M*, placed behind it. The arrow indicates the communication between the enterocœlum of the larval organ and the enterocœlum surrounding the intestine.
28. Larva in the same stage as fig. 27, from the anterior side : the position of the intestine is only indicated.
29, 30, 31. Different views of a larva on the sixth day.
29. Seen from the left side : *a*, the larval organ (the brachiolarian appendages) ; *b*, its anterior, *c*, its posterior lobe ; *d*, the button-like projection on the creeping surface of the larval organ.
30. The same as fig. 29, seen from the anterior and left side.
31. The same, seen facing the creeping surface of the larval organ.
32. Larva of the sixth day, seen from the left. The hydrocœlum has become five-lobed, 1, 2, 3, 4, 5, its five lobes ; the position of the mesentery on the other side of the digestive cavity is indicated as if seen through it. The arrows indicate the communication between the larval enterocœlum, the hydrocœlum, and the enterocœlum surrounding the digestive cavity.
33. Larva of the seventh day. The hydrocœlum is apparently shut off at *a* from the larval organ ; communication between it and the larval organ, however, is still clearly to be made out, and is indicated by the arrow ; *b*, formation of an ambulacral lobe (1) in the mesoderm below the hydrocœlum ; *c*, a band of connective tissue, not always found in this position.
34. Larva of the seventh day, from the posterior side. *L s*, the larval œsophagus ; *S s*, pouch of the digestive cavity extending towards the hydrocœlum, which later trends towards the œsophagus of the young Starfish. The madreporic canal is abnormally early developed.
35. Exterior view of the same larva, showing on an upper plane the dorsocentral plate, *C*, with interradials JR_1, JR_2, JR_3, JR_4, JR_5, and one of the terminal plates, T_3 ; on the next somewhat lower plane are the terminal plates T_1, T_3, T_4, and on a still lower plane, T_2.
36. Longitudinal section through the same larva, seen from the anterior side ; *a* shows the broad open communication between the enterocœlum of the larval organ and the hydrocœlum, as well as the communication between the dorsal pore and the enterocœlum of the larval organ.
37. View of a whole embryo, seen from the right and lower side.
38. View of a larva partly cut open, seen from the right side. *Bl''*, central blood system. *a*, mesoderm plate covered by the entoderm of the enterocœlum ; this has taken the place of the larval œsophagus, which has now disappeared.
39. A larva of the eighth day, seen from the left side.
40. A similar larva, creeping. *a* and *b* in both these figures denote the anterior and posterior larval lobes.
41. The surface of the larval organ of an embryo somewhat more advanced than figs. 39, 40.
42. Larva in about the same stage as fig. 41, seen from the right side.
43. Larva on the eighth day, seen from the right side, showing the position of the blood cavity, *Bl*, in the mesentery adjoining the fifth interradial, JR_5, in the position where the madreporic plate will eventually be formed.
44. Larva at the beginning of the ninth day, seen from the left.
45. Larva at the end of the eighth day, seen from the anterior side.
46. Larva of the ninth day, cut open close to the surface on the left, to show the shape of the hydrocœlum lobes, their unequal development, and the formation of the first and second ambulacral plates.
47. Larva of the tenth day, seen from the anterior side.
48. The same, from the anterior and left side.
49. Larva of the tenth day. This larva still retains a large larval organ : seen from the left, the section is so made as to show the relation of the five lobes of the ambulacral and antiambulacral areas.

PLATE VI.

Development of Asteroidea, *continued. Figures from* Hubert Ludwig, Louis Agassiz, Michael Sars, C. Wyville Thomson, Johannes Müller, *and* J. Koren *and* D. C. Danielssen.

1–11. *Asterina gibbosa*, continued. From H. Ludwig, Morphologische Studien an Echinodermen II., 2 Heft, 1882. Zeits. f. Wiss. Zool., XXXVII., Pls. VII., VIII.

A_1. First ambulacral plate.
A_2. Second ambulacral plate.
$A\,d_1$. First adambulacral plate.
$A\,d_2$. Second adambulacral plate.
$A\,f$. Anal opening.
$B\,l$. Blood system.
C. Centrodorsal plate.
D. Digestive cavity.
$E\,c$. Enterocœlum.
F. Terminal tentacle.
F_1. First pair of tentacles.
F_2. Second pair of tentacles.
$H\,c$. Hydrocœlum.
$J\,a$. Interambulacral plates.
$J\,m$. Intermediate plates.
$J\,R_1$, $J\,R_2$, $J\,R_3$, $J\,R_4$, $J\,R_5$. First to fifth interradial plates.
$\downarrow l$. Interradial space of the larval organ.
$\downarrow m$. Interradial space of the madreporic plate.
M. Mesentery.
$M\,s$. Mesoderm.
P. Dorsal pore.
$S\,s$. Œsophagus of Starfish.
$S\,t$. Stone canal.
T_1, T_2, T_3, T_4, T_5. First to fifth terminal plates.
1, 2, 3, 4, 5, denote the hydrocœlum and ambulacral lobes.
I, II, III, IV, V, denote the antiambulacral arm-lobes. *O* denotes the upper extremity ; *U*, the lower ; *V*, the anterior ; *H*, the posterior ; *L*, left ; *R*, right.

1. Larva at the end of the ninth day, seen from the dorsal side of a young Starfish. The abactinal region is represented as transparent, to show the five lobes of the digestive cavity, the centrodorsal plate *C*, the five interradials $J\,R_1 - J\,R_5$, and the five terminal plates $T_1 - T_5$. The remnant of the larval organ (the brachiolarian arms) is represented by *a*.
2. Larva of the tenth day, seen from the anterior extremity ; the optical section passes through the lobes 1 and 3 of the hydrocœlum ; *a b*, remnants of the larval organ.
3. Transverse section of a larva in the stage of fig. 2. The ambulacral arm lobes 2 and 3 have been cut longitudinally.
4. A young Starfish at the end of the tenth day, after the reduction of the larval organ *a* ; the mouth of the Starfish is not yet formed.
5. Young Starfish of the tenth day, seen from the abactinal side ; *a*, larval organ ; $\downarrow l$, interradial space of the larval organ ; $\downarrow m$, interradial space of the madreporic body.
6. Section across a young Starfish of the eleventh day, close to the actinal side. The water-ring is not yet closed ; at *a* are the two diverticula of the water system, which unite in a subsequent stage ; the section passes through the three-lobed digestive cavity, *S s* ; this does not yet open externally.
7. Exterior view of the soft parts of an arm of a young Starfish, in the thirteenth day. *N*, rudimentary nervous ring ; *B*, swelling at the base of the terminal tentacle, where later an eye develops.
8. The same as fig. 7, to show the course of the ambulacral canal, the tentacles, and their position with respect to the terminal, the ambulacral, and the interradial plates.
9. Starfish of the sixteenth day, seen from the actinal side, to show the general arrangement of the hard parts.
10. A young Starfish of the sixteenth day, seen from the abactinal side, about in the same stage as fig. 9. Showing the arrangement of the plates of the abactinal side, the anal opening *A f*, the odd terminal tentacle *F*, extending beyond the edge of the disk ; *S*, the young spines.
11. Taken from a young Starfish forty-two days old. The abactinal surface is removed, showing the five blind pouches of the alimentary canal, which begin to fork at the extremity to form the five pair of digestive cœca of the old Starfish ; *M*, rest of the larval mesentery ; *S p*, the five interbrachial septa ; *B s*, the interradial cœcum of the end of the alimentary canal.

12–19. *Asteracanthion flaccida.* From drawings made under the supervision of L. Agassiz, in 1848.

d. Abactinal side of the young Starfish.
p. Larval organ (brachiolarian appendages).
t. Terminal tentacles.
t', t'', t^3, t^4. First, second, third, and fourth pair of tentacles, counting from the terminal tentacle.

12. Profile view of larva, with only the terminal tentacles developed.
13. The same as fig. 12, seen from the actinal side of the young Starfish.
14. Somewhat older stage than fig. 12; besides the terminal tentacles, *t*, an additional pair of tentacles, t', has been developed.
15. The same as fig. 14, seen from the actinal side.
16. Still older stage, with a second pair of tentacles, t', developed in addition to the *t* and t''.
17. The same as figure 16, seen from the actinal side.
18. Still older stage; the larval organ, *p*, is nearly resorbed, and there are now in each arm four pairs of tentacles, t'–t^4, in addition to the terminal tentacle, *t*. In figs. 14–19, t' always denotes the last-formed tentacle, t'' the last but one; the outline of the young Starfish becomes more and more pentagonal as it passes through the stages of figs. 13 to 15, and 17.
19. The young Starfish has five well-formed arms, four pairs of tentacles, t'–t^4, a distinct and closed circular water-ring. The actinostome of the Starfish is not yet formed, and the larval organ has not been completely resorbed.

20–23. *Pteraster militaris.* From M. Sars, Oversigt af Norges Echinodermer, 1861, Pl. VI.

a. The five perianal plates.
b. Terminal arm-plates.
c. Second arm-plates.
d. Remnant of the larval organ.
e. Circular water-ring.
g. Terminal tentacle.
t', t'', t'''. Third, second, and first pair of ambulacral tentacles.

20. Young Starfish, seen from the dorsal side; *a*, the five perianal plates; *b*, the ten arm-plates.
21. One of the arms, seen from the actinal side; *b*, oldest arm-plates; *c*, younger arm-plates; *d*, remnant of larval organ; *e*, circular water-canal; *f*, ambulacral canal; *g*, terminal tentacle; t', t'', t''', third, second, and first pairs of ambulacral tentacles. The tentacles are contracted.
22. One of the arms, of a stage somewhat older than fig. 21, seen from the actinal side, with the tentacles extended.
23. Fig. 21, seen in profile.

24–32. *Asteracanthion violaceus.* From C. Wyville Thomson, On the Embryology of Asteracanthion violaceus, L. Quart. Journ. Microsc. Scien., I., 1861, Pl. VII.

24. Embryo about four hours after complete segmentation.
25. Embryo four hours later; first formation of the larval organ, the so-called pedunele, or brachiolarian arms.
26. Embryo about nine hours later, with three brachiolarian appendages.
27. Embryo about twenty-four hours old.
28. Peduncle and appendages, which have become separated by a natural process of fission from an embryo about a week old.
29. The embryo has become distinctly pentagonal; the brachiolarian appendages are fully developed. Thirty-six hours after segmentation.
30. Embryo in which the pentagonal outline of the young Starfish is well defined, with five tentacles; the brachiolarian appendages are beginning to be resorbed, and are no longer very efficient in assisting locomotion, as in the earlier stages. About eight days after segmentation.
31. Embryo five weeks after segmentation; shows the remains of brachiolar appendages, much atrophied; the actinostome of the young Starfish is indicated, and there are three pairs of tentacles in addition to the odd terminal one.
31′. Abactinal view of a young Starfish, about twelve days old, showing the arrangement of the limestone plates of that side.
32. View of the actinal surface to show the arrangement of the ambulacral plates.

33–42. *Echinaster sanguinolentus.* From M. Sars, Ueber die Entwickelung der Seesterne. Fragment aus meinen Beiträge zur Fauna von Norvegen. Archiv für Naturg., 1844, I., Pl. VI.

a. Brachiolar appendages. *b.* Tubercular brachiolar appendage. *c.* Ambulacral tentacles.

33. Egg just laid, greatly magnified. Chorion colorless; yolk, brilliant orange-red.
34. Egg three days old, in which the blastosphere has been formed.
35. Embryo just after being hatched.

36. Embryo in which the larval organs, *a a*, are forming.
37. Somewhat older embryo.
38. The young Starfish is well advanced : *c*, ambulacral tentacles ; the brachiolarian appendages, *a a*, are fully developed, and a small tubercle, *b*, has formed on the upper surface of the larval organ. Seen from the actinal side.
39. The same as fig. 38, seen from the abactinal side.
40. Somewhat older stage, seen from the actinal side : the young Starfish has now assumed a well-defined pentagonal outline.
41. The same embryo as fig. 40, seen from the abactinal side.
42. The same embryo, about two months old, seen from the abactinal side after the resorption of the larval organs.

43–46. *Echinaster Sarsii.* From J. Müller, Ueber den Allgemeinen Plan in der Entwickelung der Echinodermen (Pt. 6), 1852, Pl. 1. Abhandl. der K. Akad. der Wiss. Berlin, 1853.

a. Larval organ, odd brachiolarian arm.
b. Larval organ, paired brachiolarian arms.
c. Tubercle between the brachiolarian arms.
d. Cortical layer.
e. Inner layer.
f. Interior cavity.
f'. Cavity leading to the brachiolar appendages.
g. Digestive cavity.
h. Interior of the digestive cavity.
i. Tentacles of the Starfish.

43. Longitudinal section through an embryo.
44. Transversely longitudinal section across the brachiolarian arms.
45. Longitudinal sections of an older embryo in which the body cavity is divided into two, one of which contains the digestive cavity, and the other communicates with the larval organs.
46. A similar section through an embryo somewhat older than fig. 45.

47, 48. *Wurmförmige Asterie.* From J. Müller, Ueber den Allgemeinen Plan in der Entwickelung der Echinodermen (Pt. 6), 1852, Pl. 1. Quoted above.

a. Lateral ambulacral tentacles. *b*. Odd terminal tentacle. *c*. Spines of the actinal surface.

47. *Wurmförmige Asterie*, seen from the abactinal side.
48. The same, seen from the actinal side.

49–51. *Pteraster militaris.* From J. Koren and D. C. Danielssen, Observations sur le Développement des Astéries, in Fauna littoralis Norvegiæ, Seconde Livraison, 1856, Pl. VIII.

a. Anal opening.
b. Intestinal canal.
c. Extremity of the intestinal canal.
d. Circular water canal.
e. Madreporic canal.

49. Young embryo.
50. Young embryo which has assumed a pentagonal outline.
51. A young Starfish seen from the actinal side ; *b*, ambulacral plates ; *c*, tentacles.

Figs. 49, 50 are much younger than the stages figured by Sars ; see this Plate, figs. 20–23. Fig. 51 is about in the stage of fig. 22.

PLATE VII.

Development of ASTEROIDEA, *continued.* *Figures from* ALEXANDER AGASSIZ.

a. Anus.
b. Dorsal or water pore, madreporic opening.
c. Alimentary canal.
d. Digestive cavity.
c'. Median anal arms of Brachiolaria.
c''. Dorsal anal arms of Brachiolaria.
c'''. Ventral anal arms of Brachiolaria.
c''''. Dorsal oral arms of Brachiolaria.
*c*⁵. Ventral oral arms of Brachiolaria.
*c*⁶. Odd terminal oral arm of Brachiolaria.
f. Brachiolar arms.
f'. Branch of water-tube (*w w'*) leading into *f*.
f''. Odd brachiolar arm.
f'''. Surface warts at the base of the odd brachiolar arm (*f''*).
m. Mouth.
m'. Pistol-shaped oral pouch of œsophagus.
m''. Anal pouch of œsophagus.
o. Œsophagus.
v. Vibratile cord, anal part.
v'. Vibratile cord, oral part.
w. Water-tube, developing the abactinal area.
w'. Water-tube of Brachiolaria leading to madreporic opening (*b*), and developing the actinal area.
w w'. Portion of the water-tube of Brachiolaria formed by the junction of *w* and *w'*.

1–28. *Asteracanthion berylinus*. From Alexander Agassiz, Embryology of the Starfish, 1864 (Advance Part of Agass. Cont. Nat. Hist. U. S., V.), Pls. I., II. Memoirs Mus. Comp. Zoöl., V., No. 1, North American Starfishes, 1877, Pls. I., II.

Figs. 13–18. Scyphistoma stages.
Figs. 19–25. Tornaria stages.
Figs. 26–30. Brachina stages.
Figs. 31–34. Brachiolaria stages.

1. A mature egg, surrounded by spermatic particles, soon after artificial fecundation. The egg has assumed a spherical shape, and contains the germinative vesicle and dot. There is no trace of any interval between the yolk and outer envelope.
2. The germinative vesicle has disappeared, but the nucleolus remains.
3. The germinative dot is no longer visible; the yolk has contracted, and is separated by a slight space from the outer envelope. The egg at this early stage has all the appearance of having already gone through its segmentation, the whole yolk being made up of small spherical cells resembling very minute spheres of segmentation, although the segmentation has not yet commenced. Two hours after fecundation.
4. Shows the first trace of segmentation, consisting in a slight depression on one side of the yolk.
5. The yolk has become flattened on opposite poles; the "Richtungsbläschen" are visible on one side of the yolk.
6. Shows the yolk divided into united ellipsoids: the whole yolk rotates slowly, always in one direction, from right to left. The "Richtungsbläschen" are at one pole of the axis of segmentation.
7. The two segments of the yolk have entirely separated. The "Richtungsbläschen" are likewise isolated at one pole of the axis of segmentation.
8. The yolk segments are about to separate into four.
9. The yolk, about to divide into eight spheres.
10. The yolk is divided into sixteen spheres.
11. The spheres of the yolk have undergone two additional subdivisions since the preceding stage.
12. The segmentation has been carried on still further; the spheres of segmentation have become somewhat polygonal, and form an embryo with a spherical shell consisting of comparatively large cells.
13. An embryo after its escape from the egg; the wall is no longer of the same thickness throughout, but has become very much thickened at one pole (*a*), and the spheres of segmentation have become somewhat indistinct.
14. The thickened wall of the flattened pole (*a*) has formed a slight invagination.
15. The invagination (*a*) has increased in depth, the spheres of segmentation have entirely disappeared, the invagination (*a*) assumes somewhat the aspect of a rudimentary digestive cavity. Twelve hours after fecundation.

16. Twenty-two hours after fecundation ; the embryo has become greatly lengthened, and is cylindrical. The cavity (*d*) has slightly expanded at the closed extremity, and the walls of the embryo are somewhat reduced in thickness except at the perforated region ; the body is somewhat translucent, slightly tinged with ochre-color. The opening (*a*) still serves as a mouth, although in more advanced stages a second opening is formed which becomes the true mouth of the embryo, at which time the present mouth then becomes the anus.
17. Slightly older embryo than fig. 16, seen from the side ; the digestive cavity (*d*) is no longer in the axis, but is bent to one side (the lower side).
18. Older embryo, seen in profile ; the pouch formed at the end of the closed extremity of the bent digestive cavity (*d*) is nearer the lower side than in fig. 17, and is moving towards the slight depression (*m*, the future mouth) placed in the middle of the larva.
19. A larva somewhat more advanced, seen in profile, in which the terminal pouch of the digestive cavity has actually come into contact with the wall of the lower side at *m*. The dorsal region of the perforated extremity projects slightly beyond the depression in which *m* is placed. The digestive cavity is not yet divided into distinct regions.
20. A larva somewhat more advanced (end of the second day), seen in profile. The digestive cavity is no longer a simple bent tube, as in fig. 18 ; it is strongly contracted near the extremities ; at the distal extremity two diverticula have formed, projecting upwards (*w*) ; a second opening (*m*) has been formed at the point of contact of the former closed extremity of the digestive cavity with the lower side; this connects the œsophagus, by a short tube, with the main pouch of the digestive cavity. This second formed opening (*m*) is the true larval mouth, while the first formed opening (*a*) now becomes the anus, after having, up to this stage, performed the functions of both mouth and anus.
21. Isolated digestive cavity seen from below, showing the position of the mouth and anus on the same side of the larva. The anal extremity of the larva bending over as in fig. 24 at about this stage, thus bringing the anal opening from the extremity of the larva to the lower side. The two diverticula (*w w'*) of the digestive cavity (the future water-tubes) are so far differentiated as to be quite distinct from the digestive cavity. The walls of these diverticula are excessively attenuated, and are scarcely connected with the digestive cavity.
22. Larva somewhat older than stage of fig. 21, seen from above, in which the two small bodies, *w*, *w'*, the diverticula of younger stages formed from the pouch of the digestive cavity at its closed extremity (the problematic bodies of Müller), have entirely separated from the digestive cavity from which they were formed ; the three divisions of the original cavity into intestine, stomach, and œsophagus are plainly marked out.
23. Older larva, seen from below at the end of the third day after fecundation, showing the triangular shape of the mouth (*m*), the greater size of the problematic bodies *w*, *w'* (the water-tubes), which increase independently and at an unequal rate ; the tube *w'* communicates with the madreporic opening (*b*) ; it also shows the position of the rudimentary oral and anal vibratile crescent cords.
24. The same as fig. 23, seen in profile, to show the position of the mouth in a strongly marked depression, the great increase in size of the oral part of the œsophagus, the swelling of the stomach, and the bending of the extremity of the intestine back and downward toward the mouth, so as to make a small angle with the trend of the stomach.
25. Slightly older larva, seen from above. The principal difference between this stage and the preceding one consists in the greater increase in size of the vibratile crescents, which now form two small plastrons, and the greater size of the water-tubes. The intestine also bends so as to make, when seen in profile, almost a right angle with the stomach, which is pushed out farther toward the anal extremity.
26. More advanced larva, seen from the left profile, in which the oral pouch has assumed its characteristic pistol-shape. The stomach and intestine make a sharp angle with each other, the latter being much longer than the stomach proper. In its present aspect it closely resembles a retort, the stomach being the receiver, the intestine the tube. The anal and oral vibratile crescents are greatly extended towards the extremity of the body, the one on the oral, the other on the dorsal side.
27. A larva six days after fecundation, seen from the right profile ; the water-tubes extend beyond the opening of the mouth, the tube leading from the dorsal water-pore (madreporic body) to the water-tube (*w'*) is quite distinctly seen.
28. The same larva as fig. 27, seen from below, showing the intestine thrown to one side of the axis of the larva, the water-tubes extending along the sides of the stomach toward the anal extremity.

29–34. *Asteracanthion pallidus.* From Alexander Agassiz, Embryology of the Starfish, 1864 (Agass. Cont. Nat. Hist. U. S., V.), Pls. III., IV., VII. Memoirs Mus. Comp. Zoöl., 1877, V., No. 1, North American Starfishes, Pls. III., IV., VII.

29. Larva seen from the right profile, somewhat more advanced than any larva of *A. berylinus* raised by artificial fecundation.
30. The same larva seen from the oral side. The water-tubes have greatly increased in diameter ; they have united beyond the mouth, and also extend along the sides of the stomach so as to meet, but without unit-

ing. The slight lobes along the course of the vibratile cord indicate plainly the position of the median arms (c'), of the dorsal anal (c''), the ventral anal (c'''), and the dorsal oral arms (c''''). The greatest thickening of the vibratile cord is found at the rudimentary median arms. Beyond the mouth is shown the great development which the oral portion of the water-tube has taken. This and the preceding figure also show the mode of formation of the oral pair of ventral arms (c^5), as well as the first sign of the odd brachiolar appendage (f'').

31. Older larva, seen from the mouth side. Thus far the arms have altered but little the character of the outline of the larva. In this figure, however, some of them are sufficiently developed to be capable of considerable motion. The median arms (c') especially are far in advance of the others. The anal arms all develop so as to become more slender at first, and assume their true character earlier than the oral arms, which during the early stages are always more lobe-like, and take their final shape later than the anal arms. At the angle where the oral ventral arms and the odd arm come together, at the base of the oral arms, slight swellings are formed (f), which are the first indication of the pair of brachiolar arms (ff); the odd brachiolar arm (f'') can only be seen in a profile view (see figs. 29, 32, 33), though in this figure it can be traced as a double outline of the odd arm c^6 (f''). We can already see a constriction of the water-tube as it passes into the odd arm, and from this (nearer the mouth) are sent off two small pouches ($f'f'$), (see also figs. 32, 33,) which enter into the brachiolar pair of arms (f). The first trace of the actinal area of the future Starfish is also plainly visible (t) on the water-tube (w') on the left side of this figure.

32. Fig. 31 seen in profile.

33. An adult larva seen from the right actinal profile; the arms are in the position which they take when the larva is moving rapidly, arched towards the median arms, the brachiolarian arms alone being curved in the opposite direction from the others. In this figure the crescent-shaped ambulacral pentagon, as well as the lobed pentagonal outline of the abactinal area, is plainly seen.

34. A greatly magnified figure of a full-grown Brachiolaria, at rest, in its natural attitude, with the Starfish almost ready to resorb the larva; the obliquity of the planes in which the actinal and abactinal pentagons are situated is especially well seen in the pointed anal extremity of this Brachiolaria. No letters have been added to this figure, as the different parts can be readily distinguished by comparing it with figs. 31–33.

PLATE VIII.

Development of Asteroidea, *continued.* *Figures from* Alexander Agassiz, Johannes Müller, *and* S. Lovén.

a. Anus.
b. Dorsal or water pore, madreporic opening.
c. Alimentary canal.
d. Digestive cavity.
d′. Abactinal water-tubes in the angle of the rays of the young Starfish.
e. Eye of Starfish at the base of the odd tentacle (*t′*).
l. Dorsocentral plate.
l′. Interradial plate.
l². brachial terminal plate.
m. Mouth.
n. Opening for passage of ambulacral sucker.
o. Œsophagus.
p. Spines on edge of ray of young Starfish.
p¹. Spines of exterior rows along the abactinal surface of the rays.
p². Spines of middle row, on the abactinal surface of the rays.
p³. Central spine of the abactinal surface of the young Starfish, with centrodorsal plate (*l*).
p′ p″. Different forms of pedicellariæ.
p c. Plate at the junction of adjacent rays (ovarian plate).
r. Abactinal surface.
r′. First set of five limestone *y* rods which appear on the abactinal surface, and eventually become the terminal brachial plates (*l²*).
r″. Second set of five *y* rods to appear on the abactinal surface, and which eventually become the interradial plates (*l′*).
r¹–r⁵. The first to fifth arm-lobes of the young Starfish, *r¹* being the ray nearest the madreporic opening.
s. Actinal surface.
t t t. Tentacles or water-system lobes of the young Starfish.
t′. Odd terminal tentacle.
t″. Ambulacral tube.
t¹–t⁵. First to fifth lobes of the water system, corresponding to the first to fifth arm-lobes of the young Starfish (*r¹–r⁵*).
u. Lateral ambulacral plates, surmounted by spines.
u′. Median ambulacral plates, carrying very small spines.
w. Water-tube upon which the abactinal area develops.
w′. Water-tube communicating with the madreporic opening, upon which the actinal area is developed.

1–23. *Asteracanthion pallidus*, continued. From Alexander Agassiz, Embryology of the Starfish, 1864 (Agass. Cont. Nat. Hist. U. S., V.), Pls. V., VI., VII., VIII. Mem. Mus. Comp. Zoöl., Vol. V., No. 1, North American Starfishes, 1877, Pls. V., VI., VII., VIII.

As the figs. 1–7 are intended to illustrate the development of the Starfish proper, the anal part alone of the Brachiolaria is represented ; figs. 2–4 correspond to a Brachiolaria which has reached a stage about as advanced as that of Pl. VII. fig. 31 ; figs. 5–7 are stages of development of the young Starfish which are only found on fully grown Brachiolariæ, and in which, excepting these changes of the Starfish itself, but slight modifications take place.

1, 2, 6. Represent that profile of the anal part of the Brachiolaria, in successively more advanced stages, which shows the water-tube upon which is developed the actinal area.

3. Represents the opposite profile of the anal extremity of the Brachiolaria, showing the water-tube upon which is developed the abactinal area.

4, 7. Represent the ventral side of the anal extremity of the Brachiolaria, showing the extremities of the actinal and abactinal areas of the Starfish.

5. Represents the dorsal side of the anal extremity of the Brachiolaria, showing the opposite extremities of the actinal and abactinal areas of the Starfish. Owing to the transparency of the Brachiolaria, either the actinal or the abactinal area is always projected upon the other, when the larva is seen in profile. In the dorsal or ventral views, the angle made by the actinal and abactinal areas becomes visible.

1. Actinal profile of the anal part of the water-tube (w') of the Brachiolaria, previous to the appearance of the pentagon of lobes. In stage of Pl. VII. fig. 27.
2. Somewhat more advanced actinal profile, showing the ambulacral pentagon, as well as the position of the ten limestone rods r'–r' and r''–r'' (the terminal and interradial plates), which are seen through the thickness of the larva on the surface of the other water-tube (w). In a stage intermediate between those of Pl. VII. figs. 30 and 31.
3. A larva in the same stage as the preceding figure, seen from the opposite profile, to show the abactinal area.
4. The same larva seen from the ventral side of the Brachiolaria, to show the relative position of the pentagons of the two areas; only two of the rods of the abactinal side are seen, while the edges of three of the actinal folds (t) can be perceived, one above the other, on the footlike projection formed by the folding of the water-tube w'.
5. A dorsal view of the Brachiolaria, showing a well-advanced embryo; the arm-lobes have become indented, the arms themselves are separated by a deep cut, the y rods have extended so as to form almost a continuous network over the whole abactinal area. The actinal pentagon has assumed the shape of prominent loops projecting beyond the footlike oblique fold of the water-tube.
6. The same embryo seen from the actinal profile; the inner tentacular folds have become tipped with a triangular point. The thickness of the abactinal surface prevents the network of cells on the edge of the arms from being seen.
7. The same, from the ventral side of the Brachiolaria. This figure shows, perhaps better than any other, the relative position of the extremity of the two pentagonal warped surfaces. The rough outline of the Starfish is due to the manner in which the tubercles of the abactinal surface project above it. The Starfish in this condition is at the point of resorbing the larva. The manner in which this resorption takes place is shown on fig. 23 of this Plate.
8. Quite an advanced embryo Starfish, in which all traces of the appendages of the Brachiolaria have entirely disappeared. Each side of the pentagon of suckers is a rosette made up of seven loops; the limestone particles are deposited so as to project at the angle of the arms between the tentacular loops. The month is movable, the pentagon is not closed, and the Starfish is not yet symmetrical; the shape of the different rays is not identical.
9. Magnified view of one of the ambulacral tubes of the preceding figure, with its rudimentary tentacles.
10. The young Starfish in which the two pentagons have almost closed, and been brought into parallel planes. There has been a great increase in the size of the cut between adjoining rays; the spines also have grown longer and more pointed; the limestone points of the angle of the the rays have advanced nearer the centre. The Starfish is not quite symmetrical, nor are all the arms exactly alike.
11. The same young Starfish, from the actinal side, showing the great increase in size of the ambulacral system. The tentacles are now long pouches on each side of the main tube. The basal tentacles of one of the arms are much farther apart than all the others, and this is the last indication that the ambulacral pentagon is not closed.
12. An abactinal view of one ray, and of the centre of a young Starfish, in which the spines project far beyond the edge of the disk. The arm-plates and the interradial plates have become connected by a narrow bridge. The original limestone rods are so much thickened by additional deposits that they form elliptical cells, which have entirely lost the polygonal character of the younger stages.
13. One arm and portion of the centre of the most advanced of the young Starfishes which have been raised from the Brachiolariæ, from the actinal side. The three pairs of tentacles have suckers; the deposit of limestone of the actinal area has a cellular structure. In this stage the madreporic body is still placed on the lower side, on the very edge of the disk. There is a prominent eye-spot at the base of the odd terminal tentacle. The young Starfish represented in figs. 13 and 14 is about four months old.
14. The same young Starfish as fig. 13, seen from the abactinal side; the spines are very prominent, long, somewhat spreading, becoming sometimes even fan-shaped at the extremity. The limestone cells are gradually assuming the character of those of the adult, small cells within larger ones; the cut between the rays is very deep.
15. The same young Starfish, seen in profile, to show the great development of the abactinal area, and the Echinus-like arrangement of the spines in the young Starfish. The odd tentacle, with the eye at its base, is seen turned up between two of the spines.
16. Two rays and the centre of a young Starfish, about in the stage of fig. 12, seen from the actinal side, in which the ambulacral tube is concealed by the limestone deposit; the pair of terminal tentacles has as yet increased but little in size in comparison with the other pairs, which have become so long that they extend beyond the edges of the arms. The eye, a brilliant carmine spot, makes its appearance at about this stage. The mouth is a well-defined pentagonal opening, limited by the actinal limestone deposit.
17. One of the rays and centre of a young Asteracanthion, about one year old, seen from the abactinal side.
18. Actinal view of an arm of a young Asteracanthion, probably in its third year.
19, 20, 21. Magnified views of spines (p), and of rudimentary pedicellariæ (p', p'').

22. Odd terminal tentacle, with the eye-speck (*e*) of a young Asteracanthion about in the stage of fig. 18.
23. Shows the process of resorption of the Brachiolaria into the young Starfish ; it commences at the anal extremity, and in this case has gone on sufficiently far to leave the young Starfish riding upon the oral extremity of the Brachiolaria, which alone, with its brachiolarian and terminal arms, has retained its original shape and proportion.

24. *Bipinnaria asterigera*. From Johannes Müller, Ueber die Larven und die Metamorphose der Echinodermen, Zweite Abhandlung, (1848,) Pl. II. Abhandl. d. K. Akad. der Wiss. Berlin, 1849.

24. A Bipinnaria, 1″ in size, seen from the ventral side : *1*, upper arm (anal) ; *7*, ventral arm (oral) ; *2*, *3*, *4*, *5*, *6*, dorsal arms ; *a*, mouth ; *b*, anus ; *d*, dorsal vibratile cord ; *d′*, ventral vibratile cord ; *c*, *a′*, furrow between the vibratile cords of the arms.

25–28. *Asterias glacialis*. From S. Lovén, Études sur les Échinoïdées, 1874, Pl. LIII. Kongl. Svenska Vetens. Akad. Handl., XI., No. 7.

25. Young Asterias, 1.3 mm., seen from the ventral side : *a*, *b*, ambulacral plates.
26. The same, seen from the abactinal side. In this stage the skeleton is almost exclusively made up of the apical and of the ambulacral system : *a*, dorsocentral plate (basal) ; *b*, interradial plates (genital) ; *c*, the terminal plates (ocular). The small plates (*p*) between the terminal and the angle of the interradial plates are the first dorsal arm-plates.
27. Older specimen, 2 mm., seen from the abactinal side ; the single plate (*p*) of the preceding figure is replaced by a set of three plates. Lettering as before.
28. Another individual, 4.5 mm., seen from the dorsal side ; one of the genital plates has been pierced by the madreporite (*r*) ; in each ray a pair of dorsal water-tubes (*t r*) have made their appearance. Lettering as for fig. 26.

PLATE IX.

Development of the Echinoidea. *Figures from* Emil Selenka, Wilhelm Busch, Johannes Müller, J. W. Fewkes, H. Garman *and* B. P. Colton, *and* Alexander Agassiz.

1–16. *Echinus miliaris.* From E. Selenka, Keimblätter und Organanlage der Echiniden, 1880, Pl. V. Zeits. f. Wiss. Zool., XXXIII.

1. Free swimming blastula, optical section ; *a*, position of the future anus ; *b*, funnel-shaped depression ; *f*, segmental cavity. 16 hours after artificial fecundation.
2. Blastula with the two clusters of mesoderm cells, *m*, *m'*, which have separated from the thickened part of the ectoderm ; *a*, position of the future anus. 18 hours.
3. Commencement of the invagination. 22 hours.
4. Young gastrula, optical section ; *a*, gastrula mouth (later anus). 27 hours.
5. Gastrula, optical section ; small limestone rods have made their appearance : *u*, digestive cavity ; *m*, *m'*, accumulation of cells from which the *y*-shaped rods take their origin ; *c*, expansion of the closed extremity of the digestive cavity, from which are developed the diverticula forming the water-tubes. 43 hours.
6. Gastrula, dark mesoderm cells at the upper extremity of the larva ; the diverticulum (water-system) of the digestive cavity forms a T across its closed extremity ; the limestone rods have greatly increased in length and are surrounded by the nomadic skeleton cells. 48 hours.
7. Gastrula, after 54 hours. Optical section, showing the position of the limestone rods. The digestive cavity, D, is becoming differentiated into an œsophagus, stomach, and intestine. The water-system, *v p*, has completely separated from the digestive cavity. Lettering as before.
8, 9, 10, 11, 12. Successive stages of the digestive cavity and its diverticulum, showing the manner in which the water-system is formed as a diverticulum at the blind extremity of the digestive cavity, and how it becomes separated from it. This process takes place, according to Selenka, in less than three quarters of an hour.
13. Pluteus, after 60 hours. It has lost its cylindrical outline, the rudiments of the arms appear, and the oral and anal planes of the larva are developing in opposite directions.
14. Diagram of the same Pluteus as fig. 13, seen in profile ; α, œsophagus ; β, stomach ; γ, intestine. The skeleton is not indicated.
15. Pluteus 94 hours after fecundation : *o*, mouth ; *a*, anus (gastrula mouth) ; α, œsophagus ; β, stomach ; γ, intestine ; *v p*, right water-tube ; *p*, left water-tube, which subsequently becomes the water system of the young Echinus and the left peritoneal sac. The œsophagus, α, is capable of a considerable contraction and expansion ; the narrow passages *h* and *i*, leading from the œsophagus and intestine into the stomach, are well seen in the profile figure of the same Pluteus (fig. 16).
16. The same Pluteus as fig. 15, seen in profile. The cilia which still cover the whole Pluteus are not represented in this figure, nor in figs. 13, 14.

17–19. *Strongylocentrotus lividus.* From E. Selenka, Keimblätter und Organanlage der Echiniden, 1880, Pl. VII. Zeits. f. Wiss. Zool., XXXIII.

17. Blastula making its escape from the egg ; *d*, outer membrane.
18. The same blastula, free, optical section ; *c n*, thickened wall of the blastula at the pole where the invagination will take place.
19. Gastrula 43 hours old. The vasoperitoneal vesicle has separated from the digestive cavity. Optical section, the two first *y*-shaped limestone rods of the skeleton have appeared.

20–23. *Arbacia pustulosa.* From E. Selenka, Keimblätter und Organanlage der Echiniden, 1880, Pl. VII. Zeits. f. Wiss. Zool., XXXIII.

20. Blastula 30 hours after artificial fecundation ; *c n*, thickened wall of the blastula, where the invagination will take place ; *f*, segmental cavity ; *g*, anal pole.

21. Gastrula, optical section ; *u*, digestive cavity. 48 hours.
22. Gastrula, 68 hours old.
23. Embryo 72 hours old ; the vasoperitoneal vesicle has separated from the digestive cavity.

24–27. *Echinocardium cordatum*. From E. Selenka, Keimblätter und Organanlage der Echiniden, 1880, Pl. VII. Zeits. f. Wiss. Zool., XXXIII.

24. Blastula, 30 hours ; *a*, position of the future anus ; *f*, segmental cavity ; *g*, funnel-shaped depression in the ectodermal cells at the anal pole.
24′. Blastula showing the commencement of the invagination ; *m*, *m′*, clusters of cells of the mesoderm which have become separated from the ectoderm at the anal pole.
25. Gastrula 40 hours hold.
26. Longitudinal optical section of the same.
27. Young larva 50 hours old, optical section ; the vasoperitoneal sac has become separated from the digestive cavity ; this is now differentiated into the α, œsophagus ; β, stomach ; and γ, the intestine.

Figs. 1–27 are grouped together to show, in the earlier stages of the Pluteus of several Echini types, the formation of the mesoderm cells, the invaginations of the gastrula, the development of the vasoperitoneal sacs, and the differentiation of the original digestive cavity of the gastrula. See also Pl. X. figs. 14–33.

Figs. 28–45 are devoted mainly to showing the formation of the arms of the Pluteus and the development of the young Arbacia. See also Pl. X. figs. 32–44.

28–37. *Arbacia pustulosa*.

28, 29. *Arbacia pustulosa*. From W. Busch, Beobachtungen über Anatomie und Entwickelung einiger Wirbellosen Seethiere, 1851, Pl. XIII.

28. Young Pluteus, seen from the mouth side ; the oral extremity does not yet project beyond the level of the fold connecting the dorsal anal arms.
29. Somewhat more advanced than the preceding stage, seen from the dorsal side ; the oral extremity projects nearly as much as the dorsal arms.

30–37. *Arbacia pustulosa*. From Johannes Müller, Ueber die Gattungen der Seeigellarven, Siebente Abhandlung, (1853,) Pls. II., III., IV. Abhandl. der K. Akad. der Wiss. Berlin, 1855.

a. Anus.
d. Digestive cavity (stomach).
om. Mouth.
o. Œsophagus.
t. Tentacular lobes of water-system.

30. Young Pluteus seen from the ventral side ; somewhat older than the oldest stage copied from Busch (fig. 29).
31. The same as fig. 30, seen in profile.
32. Still older Pluteus, seen from the ventral (mouth) side ; the oral arms, mere knobs in the preceding stages (figs. 30, 31), have greatly increased in length ; first trace of the posterior anal pair of arms.
33. Still older Pluteus, seen from the dorsal side. The posterior pair of anal arms projects well beyond the general outline of the anal extremity ; the auricles are beginning to form as folds of the vibratile cord, between the dorsal and oral arms, and the second pair of oral arms is present as mere knobs at the base of the oral arms.
34. Still older Pluteus, seen from the mouth side ; the dark pigment-spots of the abactinal region of the young Arbacia are seen through the Pluteus membranes of the anal extremity ; the posterior pair of anal dorsal arms has grown rapidly since the last stage (fig. 33), exceeding in length the oral arms ; the second pair of dorsal arms is also present, equalling in length the oral arms ; the auricles are also well developed.
35. Fully developed Pluteus, with two pairs of oral arms and a smaller pair of dorsal oral arms, with large auricular arms, and the long median dorsal arms of equal length ; the tentacular lobes of the water system, *t*, are well developed, and pedicellariæ even have made their appearance on the surface of the young Arbacia. In this stage the young Arbacia is about to resorb the Pluteus.
36, 37. Young stages of Arbacia ; 36 seen from above, 37 somewhat in profile. The club-shaped spines are the young spines of the edge of the test of the young Arbacia ; the straight spines are the remnants of the Pluteus rods in process of atrophy and resorption. In the stage 37, young pedicellariæ are seen.

38–45. *Arbacia punctulata*.

38–40. *Arbacia punctulata*. From J. W. Fewkes, On the Development of the Pluteus of Arbacia, 1881, Pl. I. Memoirs Peabody Academy of Science, Sixth Memoir.

38–40. Young Plutei, showing the development of the calcareous rods : *m*, mouth ; *d*, digestive cavity. Somewhat younger than the stages of Arbacia figured by Busch (figs. 28, 29), and somewhat older than those given by Selenka (figs. 22, 23).

41. *Arbacia punctulata.* From Alexander Agassiz, Revision of the Echini, Part IV., 1874, p. 729, fig. 66. Illust. Cat. Mus. Comp. Zoöl., No. VII., Pt. IV.

41. Adult Pluteus of *Arbacia punctulata; m*, mouth. The dark spots of the anal extremity are the pigment spots of the young Arbacia.

42–43. *Arbacia punctulata.* From H. Garman and B. P. Colton, Some Notes on the Development of Arbacia punctulata, Lam., 1882. Johns Hopkins University, Baltimore, Studies from the Biological Laboratory, II., No. 2, Pl. XVIII.

42. Young Arbacia which has begun the resorption of the Pluteus; the oral part of the Pluteus is greatly shrunken (*o l*).

43. The process of resorption is more advanced, only a trace of the oral part of the Pluteus is left (*o l*), and the limestone rods of the anal arms appear like tall spines on the abactinal side of the young Arbacia. The odd tentacular suckers are very prominent.

44, 45. *Arbacia punctulata.* From Alexander Agassiz, Revision of the Echini, Pt. IV., 1874, p. 734, figs. 68, 69. Illust. Cat. Mus. Comp. Zoöl., No. VII. Pt. IV.

44. Young *Arbacia punctulata*, 1.5 mm. in diameter, including the spines, seen from the abactinal side, showing the anal system with its four plates. The apical system covers nearly the whole abactinal area, and is covered by embryonic sessile tubercles: a few pedicellariæ have made their appearance. The edge of the test carries huge flattened spines triangular in section, nearly equalling in length the diameter of the test. The ambulacral suckers are slender, some of them longer than the diameter of the test, and provided with somewhat pointed sucking disks. The whole test and the spines are thickly covered with dark violet pigment spots and patches.

45. The same as fig. 44, seen from the actinal side, showing the connected limestone deposit of the actinal surface covering the ambulacral tubes; the longest tentacles are those nearest the odd terminal tentacle; the odd tentacle is a small, short, slender tube without a sucking disk.

PLATE X.

Development of the ECHINOIDEA, *continued. Figures from* ALEXANDER AGASSIZ.

a. Anus.
b. Madreporic body.
c. Alimentary canal (intestine).
d. Digestive cavity (stomach).
e', e'', e''', e^{IV}. Arms of the Pluteus.
f. Brachiolar arms?
k. Teeth of young Echinus.
m. Mouth.
m s. Mesoderm cells.
n. Interambulacral tubercles of young Echinus.
n'. Ambulacral tubercles of young Echinus.
o. Œsophagus.
p. Pedicellariæ.
r'. First *y* rod of the Pluteus.
s'. Pigment spots of the long Pluteus arms.
s''. Interambulacral spines of young Echinus.
s'''. Young spines of embryo Echinus.
t. Tentacles.
t'. Odd terminal tentacle.
t^1, t^2. First and second pairs of lateral ambulacral tentacles.
v. Anal part of vibratile cord.
v'. Oral part of vibratile cord.
v''. Vibratile epaulettes.
w. Water-tube.
w'. Water-tube communicating with the madreporic body.

1–17. *Strongylocentrotus Dröbachiensis.* From Alexander Agassiz, Revision of the Echini, Pt. IV., 1874. Illust. Cat. Mus. Comp. Zoöl., No. VII., pp. 709, 710.

18–44. *Strongylocentrotus Dröbachiensis*, continued. From Alexander Agassiz, On the Embryology of Echinoderms. Mem. Am. Acad., IX., 1864, selection from figs. 1–25.

1. Mature egg.
2. Egg in which the germinative vesicle has disappeared after fecundation.
3. The germinative dot has also disappeared. The yolk has separated from the outer membrane, leaving an interval between it and the envelope.
4. The yolk has become depressed at one pole.
5. The same depression takes place at the two poles.

6–12. Different stages of segmentation.

6. The first trace of segmentation is a slit at one pole.
7. The yolk is divided into two large ellipsoidal masses.
8. The masses subdivided again.
9. The four spheres show a tendency to a further subdivision.
10. There are now eight spheres of segmentation.
11. There are thirty-two spheres, and they already show a tendency to form an envelope.
12. There are sixty-four spheres, and the walls of the embryo are already indicated.
13. The segmentation has gone on until the spheres are quite small, and the wall of the embryo very distinct.
14. The embryo has just escaped from the egg; the wall is thickened at one pole.
15. A slight invagination forms at the thickened pole.
16. The invagination has become somewhat deeper.
17. Older embryo more elongated, with thin walls at the upper extremity; the invagination now performs the function of a rudimentary digestive cavity.
18. Still older embryo, seen in profile; the digestive cavity is no longer in the axis of the Pluteus.
19. The same as fig. 18, seen from above.
20. Profile view of a Pluteus, somewhat more advanced than fig. 18; the digestive cavity is bent towards the ventral side of the larva.
21. Somewhat older Pluteus, at the end of the fourth day, seen from above. At the closed extremity of the digestive cavity two small diverticula have formed (*w*, w'), the first appearance of the water-tubes.

The digestive cavity itself shows the first trace of differentiation into intestine, stomach, and œsophagus.

22. Profile view of an embryo, somewhat older than fig. 21, at the beginning of the fifth day; the intestine, *c*, stomach, *d*, and œsophagus, are well separated; the anal vibratile cord (*v''*) bulges out considerably beyond the depression in the ventral side of the Pluteus.
23. Embryo at the end of the fifth day, seen from the mouth side; the water-tubes (*w*, *w'*) are only slightly connected with the digestive cavity; they also show a difference in size. The original limestone rod has given off a shoot, the rod of a new arm to be developed at *r*.
24. Fig. 23 seen from the anal extremity, to show the great change of form which has taken place from the early cylindrical shape of the embryo.
25. A profile view of fig. 23. The embryo has become pear-shaped, the œsophagus has bent over to reach the ventral side; the anal opening is also somewhat ventrally placed; the depression at *m*, where the new mouth is to be formed, is in contact with the œsophagus; the anal and oral vibratile cords have increased in prominence.
26. A profile view of an embryo, taken at the beginning of the seventh day. The mouth, *m*, is open; the water-tube *w'* reaches nearly to the dorsal surface. The currents, which previous to this stage had carried the food through the only opening, *a*, into the digestive cavity as far as *o*, and then were reversed to eject the digested matter, now come in through the mouth, *m*, pass through the œsophagus, *o*, rotate about in the stomach, *d*, and pass out through the first-formed opening, the anus, *a*, which is hereafter only used to eject the food.
27. A Pluteus at the end of the eighth day, seen obliquely from the ventral side, to show the course and shape of the vibratile cord.
28. Profile view (actinal) of a stage slightly older than that of fig. 27.
29. The same as fig. 28, seen from the ventral side.
30. Somewhat more advanced Pluteus, to show the changes the vibratile cord has undergone since the stage of fig. 27; seen obliquely from the ventral side.
31. A Pluteus during the tenth day, seen in profile, shows the beginning of the small arms c''' and c^{IV}.
32. The same as fig. 31, seen from the mouth side. The arms *c'* have been greatly developed; the differentiation of the intestine, *c*, the stomach, *d*, and the œsophagus, is quite complete. First appearance of the vibratile epaulettes, *v''*. The water-tubes have not yet united, and have not greatly increased in size from the preceding stage.
33. Profile of a Pluteus during the twenty-third day. The arm *c''* has increased greatly in length, and a considerable increase of the vibratile epaulettes is to be noticed.
34. The same as fig. 33, seen from the dorsal side, to show the relation of the rods of the arms *c'*, *c''*, c''', to each other; the water-tube *w'* shows the first indication of a large tentacular lobe.
35. Fig. 34, seen somewhat obliquely, in an attitude similar to that of figs. 27 and 30, to show the connection of the different parts of the vibratile cord.
36. A much more advanced Pluteus, fished up from the surface. The rods extending into the arms are made up of three sets of rods united by short transverse bars; the whole oral extremity of the larval body has greatly lengthened; the arms c''' and c^{IV} are longer than in the preceding stages, *c'*, *c''*, and c''' being nearly of equal length; the arms show a tendency to a paired arrangement of *c'*, *c''*, and c''', c^{IV}. Additional tentacular lobes have been formed in the water-tube *w'*, and the water-tubes have become united in the oral extremity beyond the saclike pouch of the mouth of the Pluteus.
37. Fully developed Pluteus of *Strongylocentrotus*, in which the young Sea-urchin has already encroached somewhat on the anal extremity; its spines are quite well marked; the vibratile epaulettes have acquired a great size; two very prominent spots, *s'*, *s'*, in the arms *c'*, *c''*. At the base of the oral extremity of the mouth pouch a rudimentary appendage, *f*, appears; this is perhaps the homologue of the brachiolarian appendages of the Brachiolaria of Asteracanthion. The arms *c'*, *c''*, and c''', c^{IV}, are now of nearly equal length, and arranged in pairs.
38. Fig. 37 seen from the oral extremity of the Pluteus.
39. Profile view of fig. 37.
40. A young Echinus, immediately after the resorption of the Pluteus, seen from the abactinal side. The anal opening cannot be traced in the youngest specimens, though it is very apparent in somewhat more advanced stages (*a*, fig. 43).
41. A young Echinus, somewhat more advanced than the stage of fig. 40, seen from the actinal side; the tentacles have become more slender; the odd tentacle *t'* especially, when fully extended, more than equals the diameter of the test; the interambulacral spines of this side are nearly as long as the diameter of the test. The actinal system is not well separated from the coronal test. The two tentacles nearest the actinostome are remarkable for the great development of the sucking disk.
42. The same as fig. 41, seen from the abactinal side; the spines of the abactinal area are remarkable for their fan-shaped spiny extremities.

43. Young *Strongylocentrotus*, measuring one fifteenth of an inch in diameter, including the spines; a number of long-stemmed pedicellariæ have developed on the abactinal side; the tentacles have become quite slender, and carry a comparatively large sucking disk; the spines have lost their embryonic character, and have assumed the general appearance of those of the adult. The anal system is very prominent, a large circular opening covered by a single plate, *a*, leaving the anal opening on one edge of the anal system.

44. The test of a young Sea-urchin, in the stage of figs. 41, 42, stripped of its spines, seen from the actinal side; the actinal system is comparatively large, and, as in Cidaris, the tubercles are large and few in number; no miliary tubercules are as yet formed. The teeth are simple, and the accessory parts of the jaws are not developed.

PLATE XI.

Development of ECHINOIDEA, *continued. Figures from* JOHANNES MÜLLER, AUGUST KROHN, *and* ALEXANDER AGASSIZ.

Spatangus purpureus.

1, 3, 5. From August Krohn, Ueber die Larve von Spatangus purpureus. Archiv f. Anat. Physiol. u. Wiss. Med., 1853, Pl. VII.

2, 4, 6. From Johannes Müller, Ueber die Larven und die Metamorphose der Echinodermen, Vierte Abhandlung (1850–51), Pl. VIII. Abhandl. d. K. Akad d. Wiss. Berlin, 1852.

7, 8. From Johannes Müller, Ueber die Larven und die Metamorphose der Ophiuren und Seeigel (1846), Pl. III. Abhandl. d. K. Akad. d. Wiss. Berlin, 1848.

9. From Johannes Müller, Ueber die Gattungen der Seeigellarven, Siebente Abhandlung über die Metamorphose der Echinodermen, 1855, Pl. V. Abhandl. d. K. Akad. d. Wiss. Berlin, 1855.

A. First pair of dorsal arms.
B. Second pair of dorsal arms.
C. Pair of anal arms.
D. Odd anal arm.
E. Second pair of oral arms.
F. First pair of oral arms.
G. Third pair of oral arms.
a. Mouth.
a'. Œsophagus.
b. Stomach.
b'. Intestine.
o. Anus.

1. One of the older Plutei raised by artificial fecundation, with a rudimentary odd anal arm, D, and a single pair of dorsal arms, A.
2. Older Pluteus, in which the odd anal arm, D, has greatly increased in size, and the first pair of oral arms, F, has made its appearance. Seen obliquely.
3. Older Pluteus, in which the dorsal arms, A, have still further developed. Dorsal view.
4. Older than fig. 3. The growth of the Pluteus since the last stage has been principally in the elongation of the oral part of the larva and the lengthening of the odd anal arm. Seen from the mouth side.
5. Pluteus somewhat older than stage of fig. 4. The dorsal arms, A, are nearly twice as long as in the preceding stage, and the rudiments of the second pair of dorsal arms are visible. Ventral view.
6. Older stage, in which the second pair of dorsal arms, B, is nearly as long as the first pair, A; the rudiments of the second pair of oral arms, E, have also appeared. Seen from the mouth side.
7. Still older Pluteus; the first pair of dorsal arms is somewhat longer than the second; the third pair of oral arms, G, has been developed, and the anal pair of arms, C, has likewise made its appearance.
8. Older stage, in which the resorption of the Pluteus is well advanced, the anal arms have disappeared, and a part of the oral portion of the larva has also been resorbed by the young Spatangus; the spines and ambulacral suckers of the young Urchin are well seen in the anal part of the Pluteus.
9. Fully developed Pluteus, with all its arms, just before the resorption of the Pluteus begins.

10. *Spatangoid Pluteus.* From Johannes Müller, Ueber die Gattungen der Seeigellarven, Siebente Abhandlung, 1855, Pl. V. Quoted above.

10. This Pluteus may be a younger stage of fig. 9, but, judging from the absence of the pair of anal arms and the great length of the odd anal arm, it probably does not belong to *S. purpureus*.

11. *Echinoid Pluteus.* From Johannes Müller, Siebente Abhandlung, 1855, Pl. V. Quoted above.

11. This remarkable Pluteus differs widely from all known Echinoid larvæ; it has features in common with the Brachiolaria, many of its arms being flexible, without rods. These arms are perhaps only such auricles as we find in the Pluteus of Arbacia (see Plate IX. figs. 34, 41). It is probable, therefore, that this larva will prove to be the Pluteus of a Cidaris or of a Diadema.

12–18. *Echinus lividus.* From Johannes Müller, Vierte Abhandlung (1850–51), Pl. VI., VII. Quoted above.

A. First pair of dorsal arms.
B. Second pair of dorsal arms.
E. Second pair of oral arms.
F. First pair of oral arms.
a. Mouth.
a'. Œsophagus.
b. Stomach.
b'. Intestine.
c. Anus.
d. Cord of vibratile cilia.
f. Vibratile epaulettes.

12. Pluteus on the sixteenth day after artificial fecundation; this Pluteus was remarkably slow in its development.
13, 14. Pluteus on the eleventh day after artificial fecundation, but more advanced than the preceding stage. 13, seen obliquely from the side; *x* is the outline of the depression in which the mouth is placed. 14, seen from the mouth side.
15. Somewhat more advanced Pluteus, on the seventeenth day, seen obliquely from the dorsal side, shows the relative position of the calcareous rods, of the arms, and of the cord of vibratile cilia.
16. Somewhat older Pluteus, in which the arms have greatly lengthened, and there is a slight swelling of the vibratile cord at the base of the dorsal arms, denoting the position of the future vibratile epaulettes.
17. Fully developed Pluteus, with vibratile epaulettes; the young Echinus is well advanced.
18. Stage in which the young Echinus has resorbed the greater part of the Pluteus; only a small part of the oral extremity and short pieces of the rods of the arms of the larva are left. The rudimentary embryonic spines, *x*, are quite prominent; the ambulacral suckers, *y*, are clearly seen; one of the longer tentacles projects beyond the disk, and a few pedunculated pedicellariæ have made their appearance.

19–27. *Echinocyamus pusillus?*

19–21. From Johannes Müller, Vierte Abhandlung (1850–51), Pl. VIII. Quoted above.

A. First pair of dorsal arms.
F. First pair of oral arms.
a. Mouth.
a'. Œsophagus.
b. Stomach.
b'. Intestine.

19. Young Pluteus, seen from the ventral side.
20. The same, seen obliquely in profile from the dorsal side.
21. Somewhat older Pluteus, in which the second pair of oral arms is already formed. It is somewhat problematical if the stages of figs. 19–21 are the younger stages of figs. 22–24.

22–27. From Johannes Müller, Siebente Abhandlung, 1855, Pl. VIII. Quoted above.

a. Mouth.
b. Œsophagus.
c. Stomach.
d. Intestine.
e. Anus.

22. Young Pluteus, with two dorsal and two oral arms, seen obliquely, looking into the mouth cavity.
23. Somewhat older Pluteus, seen from the dorsal side; the second pair of oral arms has made its appearance.
24. Fully grown Pluteus; the young Urchin is not yet far advanced.
25. Pluteus in which the resorption of the anal extremity is well advanced, the young Urchin occupying the whole of the anal extremity of the Pluteus; the oral extremity is still nearly unchanged.
26. The young Urchin seen in profile, after the complete resorption and disappearance of the plutean appendages. $\frac{1}{7}$‴ in diameter. The odd tentacles have already well-developed suckers.
27. The same young Urchin as fig. 26, under compression, showing the five teeth, the limestone plates of the actinostome, and the single row of embryonic spines placed round the ambitus.

28. *Echinarachnius parma?* From Alexander Agassiz, Revision of the Echini, 1874, Part IV., p. 727, fig. 65. Illust. Cat. Mus. Comp. Zoöl., No. VII. Part IV., 1874.

28. Well-advanced Pluteus, remarkable, like the problematic *Echinocyamus Pluteus*, fig. 24, for its rounded anal extremity: *a*, mouth; *a'*, œsophagus; *d*, digestive cavity; *i*, intestine; *a n*, anus. Seen from the mouth side.

29. *Echinus acutus?* From Johannes Müller, Ueber die Larven und die Metamorphose . . . . (1846), Pl. V. Quoted above.

29. Fully developed Pluteus, with rounded anal extremity, large vibratile epaulettes, and comparatively short arms. Seen from the mouth side. A, first pair of dorsal arms; B, second pair of dorsal arms; *a*, mouth; *a'*, œsophagus; *b*, digestive cavity; *d*, cord of vibratile cilia; *e*, calcareous rods of arms; *f*, vibratile epaulettes.

30. *Echinus brevispinosus.* From Johannes Müller, Siebente Abhandlung, 1855, Pl. I. Quoted above.

30. Fully developed Pluteus, seen from the dorsal side. This Pluteus is remarkable for the short pair of anal arms developed at the posterior extremity.

PLATE XII.

Development of Echinoidea, *continued.* *Figures from* Alexander Agassiz *and* C. Wyville Thomson.

Young Stages of

1–3. *Goniocidaris canaliculata.*
4. *Dorocidaris papillata.*
5, 6. *Asthenosoma hystrix.*
7. *Diadema setosum.*
8–12. *Mellita sexforis.*
13–14. *Mellita testudinata.*
15, 16. *Mellita longifissa.*
17–22. *Echinarachnius parma.*
23, 24. *Encope emarginata.*
26–29. *Conolampas Sigsbei.*
30–35. *Hemiaster cavernosus.*
36, 36′. *Spatangus purpureus.*
37–40. *Brissopsis lyrifera.*

1–3. *Goniocidaris canaliculata.* From Alexander Agassiz, The Zoology of the Voyage of H. M. S. Challenger, Vol. III. Part IX. Report on the Echinoidea, Pl. II., London and Edinb., 1881.

1. Young specimen, 2 mm. in diameter, seen from the abactinal side.
2. The same as fig. 1, seen from the actinal side.
3. Another young specimen, 3 mm. in diameter, belonging to the long spined type of the species.

4. *Dorocidaris papillata.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. II[c]. Ill. Catal. Mus. Comp. Zoöl., No. VII. Part II., 1872, Pl. II[c].

4. Young specimen, seen from the abactinal side, partly denuded. 2.4 mm in diameter.

5, 6. *Asthenosoma hystrix.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. II[c]. Quoted above.

5. Part of test of young specimen, measuring 3.1 mm. in diameter, seen from the abactinal side.
6. Part of test of same, seen from the actinal side.

7. *Diadema setosum.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. II[c]. Quoted above.

7. Young specimen, measuring 2.4 mm. in diameter, seen in profile, showing the anal tube projecting between the spines beyond the level of the abactinal surface.

8–12. *Mellita sexforis.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XI. Quoted above.

8. Young specimen, 2.4 mm. in diameter, having a Laganum-like shape ; the posterior interambulacral lunule is not as yet to be seen from the abactinal side.
9. The same from the actinal side, deeply concave, showing the commencement of the posterior interambulacral lunule.
10. Young specimen, 4 mm. in diameter, seen from the abactinal side ; first trace of the posterior lunule on the abactinal side.
11. Young specimen, measuring 10.1 mm. in diameter, from the abactinal side. The ambulacral lunules all present, in different stages of growth.
12. Young specimen, measuring 12.7 mm. in diameter, with all the ambulacral lunules completely pierced through and well formed.

13–16. *Mellita testudinata* and *longifissa*, in which the lateral lunules are formed from notches in the edge of the test. From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XI. Quoted above.

13, 14. *Mellita testudinata.*

13. Posterior interambulacrum of fig. 14, showing the posterior interambulacral lunule, which in this type is formed from the lower side, as in *M. sexforis*, and forces its way through the test to the abactinal surface.
14. Young specimen (¾), seen from the abactinal side ; the edge of the test shows as yet no trace of the notches so well developed in fig. 15.

15, 16. *Mellita longifissa.*

15. Young specimen, natural size, in which the notches forming the ambulacral lunules commence to close, seen from the abactinal side.

16. Part of test of a young specimen, about $\frac{3}{4}$ of an inch in diameter, in which the ambulacral lunules have completely closed; seen from the abactinal side.

17–22. *Echinarachnius parma.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XII. Quoted above.

17. Young specimen ($\frac{1}{1}^{0}$), seen in profile, elongated Echinometra-like stage.

18. The same as fig. 17, seen from the abactinal side; the anus at this stage opens above the ambitus.

19. Somewhat older stage ($\frac{2}{1}$), seen from the abactinal side; the anal opening is placed nearer the ambitus.

20. Older than the preceding stage ($\frac{3}{1}$), seen from the abactinal side; the outline has become somewhat more elliptical.

21. Older stage, seen from above ($\frac{5}{1}$). In the abactinal part of the ambulacra the pores have become conjugated.

22. Still older stage, seen from above ($\frac{3.3}{1}$); the abactinal part of the ambulacra has become slightly petaloid; the anal opening is partly on the ambitus.

23, 24. *Encope emarginata.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XII. Quoted above.

23. Young specimen in the Moulinsia stage ($\frac{1.3}{1}$), showing the first trace of the posterior interambulacral lunule on the actinal side.

24. Young Encope, natural size. The posterior interambulacral lunule has forced its way through from the actinal to the abactinal surface, and there are traces of the lateral ambulacral notches, which are to form the lunules (which may remain closed or open) of the older stages.

26–29. *Conolampas Sigsbei.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XVI. Quoted above.

26. Young specimen, seen from the abactinal side, partly denuded. 4 mm. in diameter.

27. The same, seen from the actinal side; the anal opening is on the sloping posterior edge of the ambitus of the test.

28. The same, seen in profile, showing the position of the anal system.

29. Young specimen, in its Echinolampas stage, measuring 12.7 mm. in diameter; seen in profile.

30–35. *Hemiaster cavernosus.* From Alexander Agassiz, Report on the Echinoidea of the "Challenger," 1881, Pl. XX^{a}. Quoted above.

30. One of the lateral ambulacral petals of a gravid female, showing the mode in which the young embryos are carried in the deeply sunken petaloid ambulacra. From C. Wyville Thomson, Notice of some Peculiarities in the Mode of Propagation of certain Echinoderms of the Southern Sea. Journ. Linn. Soc. Zoölogy, XIII., 1876, p. 70, fig. 9.

31. Young, 2 mm. in diameter, taken from the pouch of the petaloid ambulacra, still somewhat circular, with straight primary spines, seen from the abactinal side.

32. Somewhat older than the preceding stage, 3 mm. in diameter; the test carries curved primary spines, seen from the abactinal pole.

33. Young, in about the stage of fig. 32, denuded of spines, showing the simple ambulacral pores, the large anal opening, within the broad peripetalous fasciole, and the ring of large primary tubercles, forming its inner edge; about 3 mm. in diameter.

34. The same as fig. 33, somewhat less magnified, seen from the actinal side.

35. Young Hemiaster, measuring 5.5 mm. in diameter; the anal system is now removed from within the peripetalous fasciole to the outer edge of the broad peripetalous fasciole; seen from the abactinal side.

36, 36′. *Spatangus purpureus.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XI^{c}. Quoted above.

36. Young specimen, seen from the abactinal side ($\frac{3}{1}$), showing the straight simple ambulacra of the future petaloid system of the abactinal part of the test.

36′. The actinostome of the same; the posterior actinal lip is as yet scarcely developed.

37–40. *Brissopsis lyrifera.* From Alexander Agassiz, Revision of the Echini, Part II., 1872, Pl. XIX. Quoted above.

37. Young Brissopsis, measuring 5.6 mm. in diameter, from the abactinal side; shows the huge ambulacral tentacles (provided with suckers) of the odd ambulacral area, within the slightly dumb-bell-shaped peripetalous fasciole. The anal system is placed between the posterior edge of the abactinal and of the subanal fasciole.

38. Profile of same, showing the bevelled anterior extremity of the test, surrounded by the peripetalous fasciole.

39. Peripetalous fasciole of a young specimen, measuring about 3.6 mm. in longitudinal diameter; 5 : 4 pairs of simple pores in the anterior, and 4 : 3 pairs in the posterior lateral ambulacrum. There are from five to six simple pores in the odd anterior ambulacrum.

40. Peripetalous fasciole of an older stage, in which the fasciole has become undulating, and the lateral ambulacra somewhat petaloid.

PLATE XIII.

Development of HOLOTHUROIDEA. *Figures from* JOHANNES MÜLLER *and* ELIAS METSCHNIKOFF.

1–11. *Synapta* (*Auricularia with calcareous wheels*).

1, 3, 4. From Johannes Müller, Ueber die Larven und die Metamorphose der Echinodermen, Zweite Abhandlung, 1848, Pl. IV. Abhandl. d. K. Akad. d. Wiss. Berlin, 1849.

2, 5–11. From Johannes Müller, Ueber die Larven und die Metamorphosen der Holothurien und Asterien (Pt. 3), (1849–50,) Pls. I., II., III. Abhandl. d. K. Akad. d. Wiss. Berlin, 1850.

a. Mouth.
b. Œsophagus.
c. Digestive cavity.
c'. Intestine.
d. Dorsal part of the simple vibratile cord.
d'. Oral part of the vibratile cord.
d''. Passage of vibratile cord from the oral to the dorsal cord.
e. Anus.
g. Dorsal pore.
h. Tentacular rosette of the water system.
i. Tentacular lobes of the water system.
o. Calcareous wheel.

1. Young Auricularia, seen from the ventral side.
2. Somewhat older Auricularia, seen from the ventral side.
3. Older stage, in which the arms are developed.
4. Somewhat older Auricularia ; the tentacular lobes of the water system, *i*, are well seen.
5. About in the same stage as the preceding, seen obliquely from the dorsal side.
6. Auricularia at the time of the metamorphosis ; the lateral arms have disappeared, and broad transverse bands of vibratile cilia have been formed.

7–11. *Synapta, continued.*

a. Digestive cavity.
b. Anal opening.
c. Circular ring of the water system.
c'. Polian vesicle.
c''. The five branches of the circular ring leading to the tentacles.
d. Vesicles (otoliths) with granules round the oral water-ring.
e. Calcareous skeleton of the oral ring.
f. Tentacular chamber.
g. Canal with the crescent-shaped limestone arc.
h. Lateral muscular bands.
i. Calcareous gland at the anal extremity.
k. Cavity in which the tentacles are developed.
l. *y* rods of the oral calcareous ring.
m. Intestine.
n. Position of the cavity where the tentacles eventually break through.

7. Synapta pupa, somewhat compressed, and somewhat older than the preceding stage.
8. Synapta pupa, somewhat more advanced than the preceding stage.
9. Young creeping Synapta.
10. Young Synapta, somewhat compressed.
11. Young Synapta, still older, compressed.

In figs. 9–11 the tentacles of the young Synapta have forced their way through the actinal extremity of the pupa, and the broad transverse bands of vibratile cilia disappear with advancing development.

12–17. *Synapta, continued.* From Elias Metschnikoff, Studien über die Entwickelung der Echinodermen und Nemertinen, 1869, Pls. I., II. Mém. Acad. Imp. de St. Pétersbourg, VII^e Sér., XIV., No. 8.

c. Cutis.
c c. Œsophagus.
c d. Cavity of the lateral disk.
d'. Left water-tube.
d r. Right water-tube.
p a. Dorsal pore.
s. Stomach.
s c. Outer layer of the lateral disks.
s i. Inner layer of the lateral disks.
t^{1}–*t*^{4}. First to fifth tentacular lobes of the oral ring of tentacles.
v a. Original pouch of the water system.
v l. Otoliths round the oral water-ring.

12. A very young Auricularia, with yellow pigment spots. This figure is not a younger stage of the following ones, which all belong to Synapta.
13. Young Auricularia, in which the water system pouch and the lateral disks have not yet appeared.
14. Older Auricularia, in which the original problematic body has divided into two, forming the two lateral disks.
15. The lateral disks have now assumed their characteristic appearance, and the water system has become five-lobed.
16. Somewhat more advanced Auricularia ; the water system shows a secondary set of smaller lobes between the larger ones, and has taken a horseshoe shape ; the lateral disks have increased in size.
17. Shows the horseshoe-shaped water system, with a portion of the left water-tube.

Figs. 13–17 correspond to the period included between the stages figured by Müller. See above, figs. 1–3.

18. *Auricularia with calcareous gland.* From Johannes Müller, Ueber die Larven und die Metamorphose der Holothurien und Asterien (Pt. 3), 1849–50, Pl. IV. Quoted above.

18. Auricularia, seen from the ventral side. *a*, mouth ; *b*, œsophagus ; *c*, digestive cavity ; *d*, intestine ; *e*, anus ; *f*, calcareous gland ; *g*, gray granulation covering *f*.

19. *Auricularia with eleven spheres.* From Johannes Müller (Pt. 3), Pl. IV. Quoted above.

19. Adult Auricularia, seen from the oral side. *a*, mouth ; *b*. œsophagus ; *c*, stomach ; *e*, problematic body (lateral disk) ; *g*, depression in which the mouth is placed.

20–32. *Auricularia with elastic spheres.*

20–22, 29. From Johannes Müller, Ueber die Larven und die Metamorphose der Echinodermen, Vierte Abhandlung, 1850–51, Pl. 1. Abhand. d. K. Akad. d. Wiss. Berlin, 1852.

23–28, 30–32. From Johannes Müller, Ueber den Allgemeinen Plan in der Entwickelung der Echinodermen (Pt. 6), 1852, Pls. III., V., VI. Abhand. d. K. Akad. d. Wiss. Berlin, 1853.

20–21. Auriculariæ in the stage of development preceding the cylindrical form. 20 is seen from the dorsal side, 21 from the ventral side.

a. Mouth.
b. Œsophagus.
c. Stomach.
c'. Intestine.
d. Vibratile cord.
e. Problematic bodies.
f. Lobes of the oral tentacular system.
g. Calcareous ring of dorsal pore.
h. Water system.
h'. The eleven elastic spheres.
i. Calcareous gland.
o. Anus.

22. Auricularia somewhat younger than the preceding stages, at the time when the calcareous ring of the dorsal pore begins to form.

a. Mouth.
b. Œsophagus.
c. Digestive cavity.
d. Intestine.
e. Anus.
f. Tentacular system.
g. Calcareous ring of the future madreporic opening.
o. Calcareous sphere.
x. Part of the bilateral vibratile cord, which disappears.
I, II, III, IV, V. Portions of the bilateral vibratile cord, which become the first to fifth transverse ciliated bands.
3', 4'. Lobes of the dorsal part of the bilateral vibratile cord, which become part of the third and fourth transverse ciliated band on the dorsal side.

23. Fully developed larva, of which the mouth and œsophagus can still be seen. The bilateral vibratile cord is in process of passing into the transverse ciliated band.
24. A pupa without a mouth, seen obliquely from the ventral side ; on the ventral side only can the anterior part of the bilateral vibratile cord be recognized ; the posterior transverse ciliated bands are fully formed.
25. Another pupa without a mouth, seen from the dorsal side ; the transverse ciliated bands are not yet all closed ; the first and second are not yet complete.
26. A pupa shortly before the oral tentacles force their way through ; 1', dorsal part of the first vibratile cord, I.
27. A pupa, still pelagic ; the tentacles have just forced their way through the anterior extremity.
28. Somewhat older pupa, in which the membrane uniting the tentacles and connecting with the perisome is developed.
29. Young Holothuria, in which, besides the transverse ciliated bands, traces of the bilateral ciliated cord can still be seen.
30. Young Holothuria, with a ventral sucker, under compression, seen in profile, showing the ventral ambulacral canal and its vesicle connecting the sucker with the circular canal.

31. Young Holothuria, about in the stage of fig. 30; the vibratile cilia have disappeared, and the young Holothurian now creeps by means of its tentacles and ambulacral sucker.
32. Young Holothuria, somewhat older, under compression, seen from the dorsal side. The circular oral canal, the stone canal, the Polian vesicle, and the ventral ambulacral canal, are well seen.

33–37. *Auricularia with dendritic and calcareous gland.*

33–35, 37. From Johannes Müller, Ueber die Larven und die Metamorphose der Holothurien und Asterien (Pt. 3), 1849–50, Pl. V. Quoted above.

36. From Johannes Müller, Ueber die Larven und die Metamorphose der Echinodermen, Vierte Abhandlung, 1850–51, Pl. 1. Quoted above.

33, 34. Two successive stages of the pupa, under compression.
35. Holothurian larva of the same, with free tentacles. *a*, digestive cavity; *c*, circular canal; *c'*, Polian vesicle; *c''*, the five branches of the circular oral canal leading to the tentacle; *e*, calcareous oral ring; *f*, tentacles; *g*, stone canal, with its calcareous ring; *h*, the lateral elastic spheres; *h'*, the odd terminal anal sphere: *i*, the terminal anal dendritic gland; *k*, the remnants of the vibratile cord; *l*, transverse bands of vibratile cilia.
36. Somewhat more advanced young Holothuria, with a small ventral ambulacral sucker: the vibratile cilia of the transverse bands have disappeared. *d*, the tentacular-like bodies at the base of the oral tentacles along the calcareous ring; *f*, circular canal; *f'*, Polian vesicle; *g*, stone canal and its calcareous ring; *o*, extremity of the ventral ambulacral canal.
37. Young Holothuria, in a stage intermediate between figs. 35 and 36.

PLATE XIV.

Development of HOLOTHUROIDEA, *continued. Figures from* EMIL SELENKA, *and* D. C. DANIELSSEN *and* J. KOREN.

1–12. *Holothuria tubulosa.* From E. Selenka, Zur Entwickelung der Holothurien (Holothuria tubulosa und Cucumaria doliolum), Ein Beitrag zur Keimblattertheorie, 1876, Pls. IX., X. Zeits. f. Wiss. Zool., XXVII.

a. Anal opening.
b l. Blastoderm.
e k. Ectoderm.
e n. Entoderm.
f. Segmental cavity.
m. Mesoderm.
m'. Exterior mesodermal plate.
m''. Interior mesodermal plate.
o. Mouth.
w. Cord of vibratile cilia.
x. Water-system pore.
A. Œsophagus.
B. That part of the digestive cavity from which the vasoperitoneal sac has separated.
H. Stone canal.
N. Nucleus.
P. Peritoneal sac.
Pr. Right peritoneal sac.
Pl. Left peritoneal sac.
u. Original digestive cavity of larva.
V. Water-system sac.
Vp. Vasoperitoneal sac.

1. Six hours after fecundation. Optical section. *n*, nucleolus ; *α*, membrane of egg.
2. Blastula, fifteen hours after segmentation ; the segmentation is nearly complete. *s*, spermatozoön ; *μ*, micropyle. Many of the blastoderm cells already have a ciliated lash. The blastoderm rotates slowly and irregularly within the egg membrane.
3. Gastrula, twenty-three hours after fecundation ; longitudinal optical section. Commencement of the invagination ; a few cells, the mesoderm, have separated from the ectoderm ; the egg membrane has been ruptured, and has disappeared.
4. A transparent larva, seen from the ventral side, forty-four hours after fecundation ; the digestive cavity, *u*, already shows a constriction, the point of subsequent separation of the vasoperitoneal sac from the distal extremity of the digestive cavity. *R*, green bodies of the vibratile cord containing cells.
5. Optical section of a larva, fifty-one hours after segmentation ; the vasoperitoneal sac, *Vp*, has become separated from the anal part of the digestive cavity, *B*.
6. Diagrammatic profile view of the same larva. Formation of an atrium, *A*, the future œsophagus, by invagination of the blastoderm. The vibratile cords and mesoderm cells have not been drawn.
7. Optical section of a larva, sixty-nine hours after segmentation, seen from the dorsal side. *b*, blood cells in the vasoperitoneal sac ; *R*, the green granules, containing cells of the vibratile cord ; *p*, contents of the digestive cavity. The œsophagus and intestine are now connected ; the vasoperitoneal sac is pushed to the left side.
8. The transparent larva, seventy-one hours after fecundation. *s t*, vertical axis of the larva when swimming in a natural attitude, and round which it slowly rotates, moving forward in long spirals at the same time.
9. The transparent larva, a hundred hours after the fecundation. The vasoperitoneal sac has divided into three distinct sacs, the water-system sac, and the two lateral disks.
10. Diagrammatic profile view of fig. 8.
11. Diagrammatic profile view of fig. 9 ; a few mesoderm cells, *q*, round the stone canal, *x*, have been indicated.
12. Sketch of the digestive cavity and the surrounding parts of the same larva (fig. 9), a few hours later (seven hours).

13–27. *Holothuria tremula.* From D. C. Danielssen and J. Koren, Observations sur le Développement des Holothuries, 1856, Pls. VII., VIII. In Fauna littoralis Norvegiæ, par Dr. M. Sars, J. Koren, et D. C. Danielssen, Seconde Livraison, 1856, Pls. VII., VIII.

13. Young embryo, recently hatched ; still covered with vibratile cilia.
14. Somewhat older embryo, with a mouth opening, *a*.

15. Slightly older than the preceding figure. *b*, stomach.
16. Young embryo, in which the depression *b* indicates the point where the five tentacles are to force their way through.
17. Embryo, somewhat compressed, to show the calcareous ring, *a*, round the base of the stone canal, *b*.
18. Embryo, seen from the ventral side, compressed. *a*, mouth ; *b*, circular ambulacral ring ; *c*, the five primary ambulacral tentacles ; *d*, the five small calcareous tentacular appendages of the circular canal ; *e*, the stone canal.
19. Embryo, seen from the mouth side. *a*, mouth ; *b*, depression for the five primary ambulacral tentacles of the circular canal ; *c*, depression for the passage of the first pair of ventral ambulacral tentacles.
20. Embryo, seen from the ventral side, compressed. *a*, mouth ; *b*, circular vascular ring ; *c*, ambulacral tentacle.
21. Embryo, in which the oral tentacles have forced their way through ; seen from the dorsal side, with the tentacles protruded.
22. Embryo, about in the stage of fig. 21, seen from the side, compressed. *a*, mouth ; *b*, circular canal ; *c*, oral tentacle ; *d*, stone canal ; *e*, Polian vesicle ; *f*, stomach ; *g*, intestine.
23. Young embryo, somewhat older than the stage of fig. 21, seen in profile.
24. Embryo, about in the stage of fig. 23, seen in profile, under compression. *a*, mouth ; *b*, digestive sac ; *c*, anal, and *d*, oral tentacles ; *e*, the vesicles of the circular vascular ring at the base of the oral tentacles ; *f*, calcareous oral ring ; *g*, the five longitudinal water-canals ; *h*, water-tubes leading to the base of the ambulacra ; *i*, ambulacral tentacles of the ventral side ; *k*, Polian vesicle ; *l*, stone canal ; *m*, circular oral vascular ring.
25. Young embryo, seen from the dorsal side, with the first-formed five oral ambulacral tentacles branching, and with five new tentacles placed in between them.
26. Embryo, about in the stage of fig. 25, seen from the mouth side under compression. *a*, the ten oral tentacles ; *b*, mouth ; *c*, membranous ring round the actinostome ; *d*, outline of the oral calcareous ring ; *e*, circular water-ring ; *f*, Polian vesicle ; *g*, longitudinal water-canal ; *h*, branch of water-canal leading to the ventral ambulacral suckers ; *i*, ventral ambulacral suckers ; *k*, transverse muscular bands ; *l*, longitudinal muscular bands ; *m*, stone canal ; *n*, anus.
27. Embryo, seen from the dorsal side, with three pairs of ventral ambulacral tentacles, and ten branching oral tentacles.

PLATE XV.

Development of Holothuroidea, *continued, and Comparison of* Echinoderm Larvæ. *Figures from* Emil Selenka *and* Johannes Müller.

1–13. *Cucumaria doliolum.* From E. Selenka, Zur Entwickelung der Holothurien (Holothuria tubulosa und Cucumaria doliolum), Ein Beitrag zur Keimblättertheorie, 1876, Pls. XI., XII. Zeits f. Wiss. Zool., XXVII.

a. Anal opening.
b l. Blastoderm.
c k. Ectoderm.
c n. Entoderm.
f. Segmental cavity.
m. Mesoderm.
m'. Outer mesoderm plate.
m''. Inner mesoderm plate.
o. Mouth.
w. Cord of vibratile cilia.
x. Water-system pore.
A. Œsophagus.
B. Stomach from which has separated the vaso-peritoneal vesicle.
H. Stone canal.
N. Nucleus.
P. Peritoneal sac.
P r. Right peritoneal sac.
P l. Left peritoneal sac.
u. Original digestive cavity of larva.
V. Water-system sac.
V p. Vasoperitoneal sac.

1. Egg found floating on the surface, in process of segmentation. *n*, germinative vesicle.
2. Completely segmented blastula. *s*, the part of the blastoderm where the invagination will take place.
3. The blastula has become larger. *a*, position of the future anus ; *m*, mesoderm cells.
4. Gastrula at the end of the second day ; longitudinal section. The migratory cells have accumulated in part towards the ectoderm at *d*, to form later the circular muscular system, and in part remain free in the segmental cavity. *s*, the part of the blastoderm where the invagination to form the digestive cavity can be traced by the slight depression at that pole.
5. Longitudinal section of an older gastrula.
6. Sagittal section of larva at the end of the fourth day.
7. *A'*, *B'*, *C'*, show the mode of formation of the water system, and of the two peritoneal sacs as diverticula from the original digestive cavity ; *h*, the point where the fully formed invaginated œsophagus strikes the digestive cavity.
8. Free swimming embryo. ξ, oil globule of the head.
9. Section of a larva, about in the stage of fig. 8. Lettering as before, with the following additions : —

   E. Circular vascular ring, with the five oral tentacular vesicles.
   F. The five ambulacral canals.
   G. The ventral ambulacral canal, with two ambulacral tentacles.
   X. Stone canal.
   J. Spheres of food in the stomach.
   K. Anterior lobe of embryo.
   P'. Wall of the peritoneal sac.
   δ. Cells with lashes, originating from the vibratile cord.
   +. Polian vesicle. (This is cut off.)

10. Older embryo, swimming freely.

    T. The five oral tentacles, which can be nearly entirely contracted.
    G. The two ventral ambulacral tentacles, with rudimentary sucking disks.
    ξ. Oil globule in anterior part of the head.

11. Young Cucumaria creeping. The bands of vibratile cilia have disappeared ; the anterior portion of the young Cucumaria is rounded, and the oil globule of the interior has been resorbed. *D*, ventral ambulacral tentacles, with calcareous sucking disks ; *S*, calcareous plates of the ectoderm.

12–13. *Abnormal Blastulæ of Holothuria tubulosa.* From E. Selenka, Zur Entwickelung der Holothurien, 1876, Pl. XIII. Quoted above.

14–27. *Homologies of Echinoderm Larvæ.* From Johannes Müller, Ueber den Allgemeinen Plan in der Entwickelung der Echinodermen, Pt. VI., 1852, Pl. II. Quoted above.

A. Anterior or oral plastron.
B. Posterior or anal plastron, in which is placed *o*, the anal opening.
D. Intermediate oral area, in which is placed *C*, the mouth, and *a*, the anterior, *b*, the posterior edge of the transverse part of the oral vibratile cords; *c*, the connecting vibratile cord between the oral and anal plastrons.
d. Posterior lobe of the vibratile cord of the oral plastron.
d'. Anterior lobe of the vibratile cord of the anal plastron.
e, *e'*. Arms of the anterior and posterior plastrons on the oral side.
g, *g'*. Arms of the anterior and posterior part of the dorsal vibratile cord.
x, *x*. Processes forming in Echini arms at the anal extremity, not in the line of the vibratile cord.
M. Connected vibratile cord of the dorso-anal system.
N. Connected vibratile cord of the oral ventral plastron.
y, *y*. Brachiolarian appendages of the Starfish larva. The whole of the Brachiolaria of fig. 27, beyond the brachiolarian arms, corresponds to the Starfish larval organ, such as has been figured by Sars, Thomson, Ludwig, and others.

14–16. Shows the development of an Auricularia from the typical Echinodermal larva, fig. 14.
17–19. The development of an Ophiuran Pluteus from the typical Echinodermal larva, fig. 17.
20–23. The development of an Echinoid Pluteus from the typical Echinodermal larva, fig. 20.
24–27. The development of a Starfish Brachiolaria from the typical Echinodermal larva, fig. 24.

For modifications of the typical form of development of the Holothurians, see Pl. XIV. figs. 13–27, Pl. XV. figs. 5–11.
For modifications of the typical form of development of the Ophiurans, see Pl. III. figs. 1–20, 26–31.
For modifications of the typical form of development of the Starfishes, see Pl. V. figs. 1–4, 15–49, Pl. VI.
For modifications of the typical form of development of the Sea-urchins, see Pl. XII. figs. 30–34.

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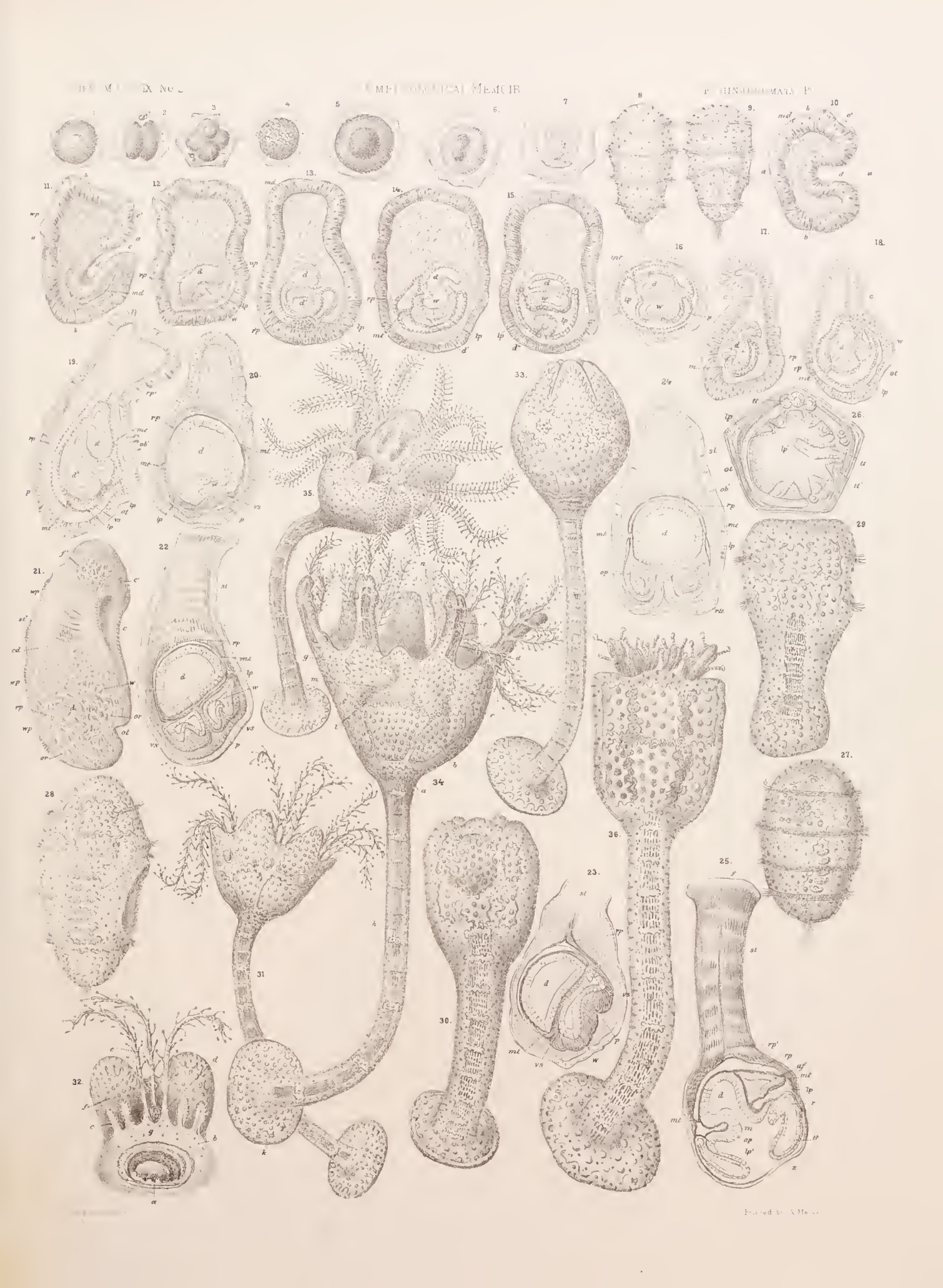

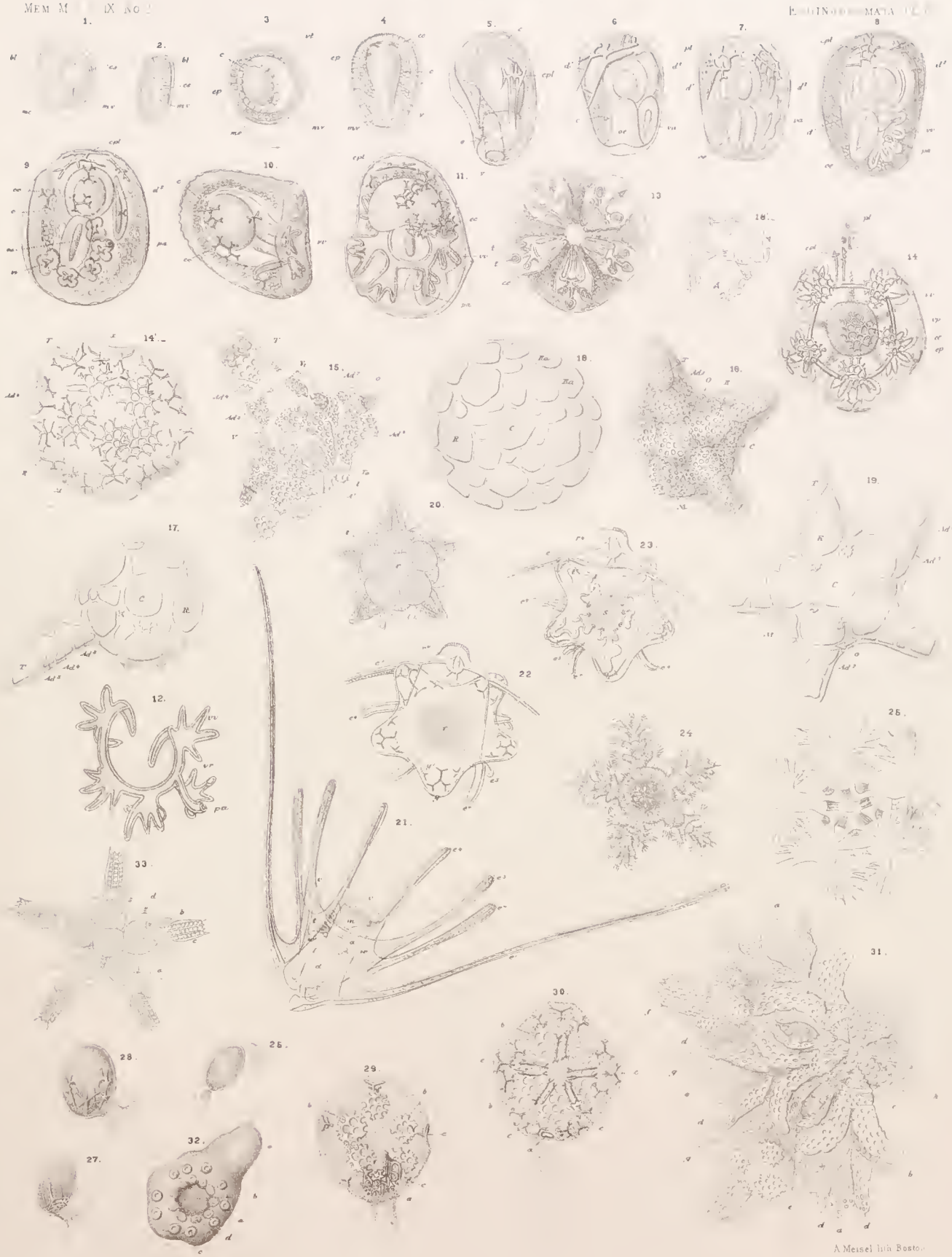

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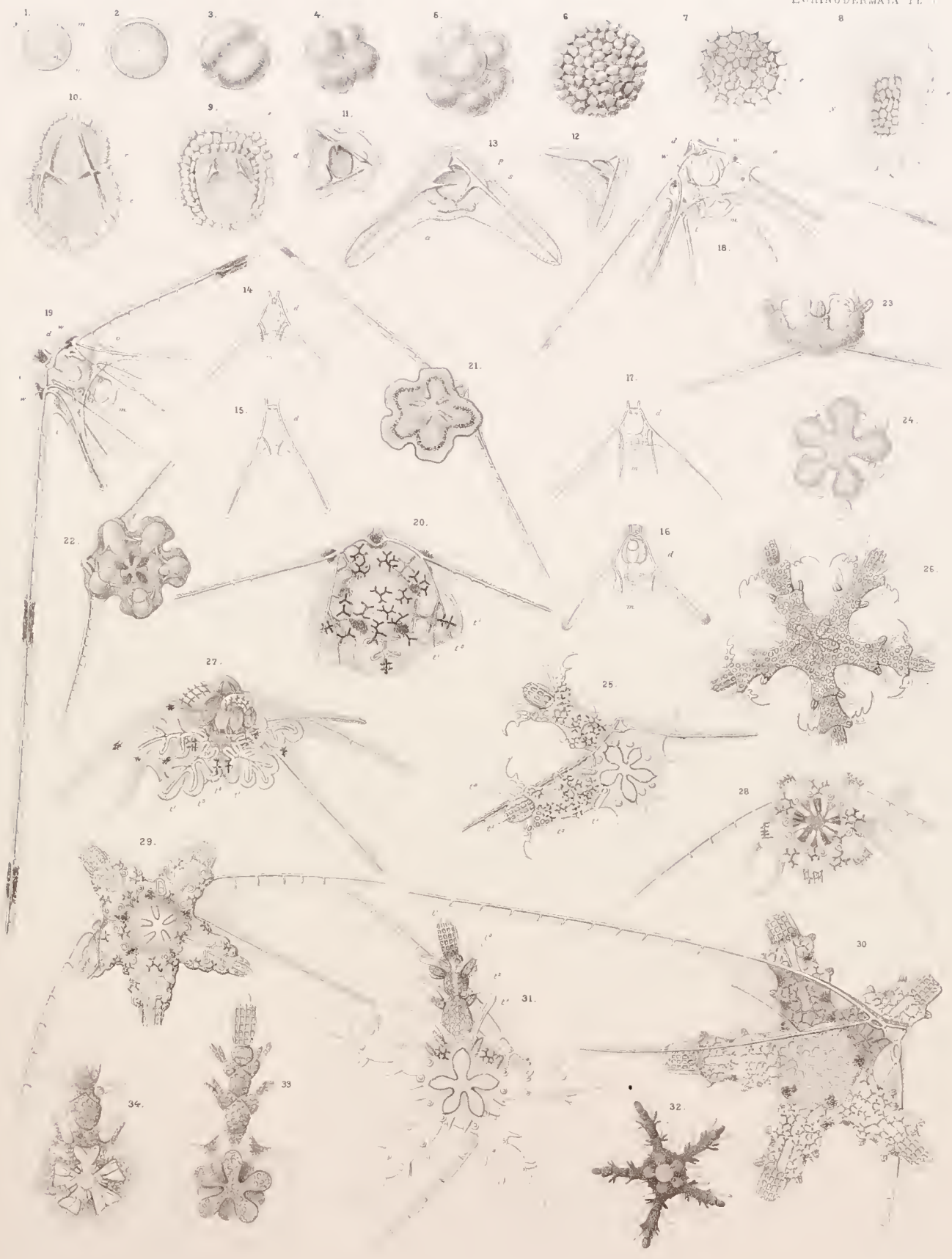

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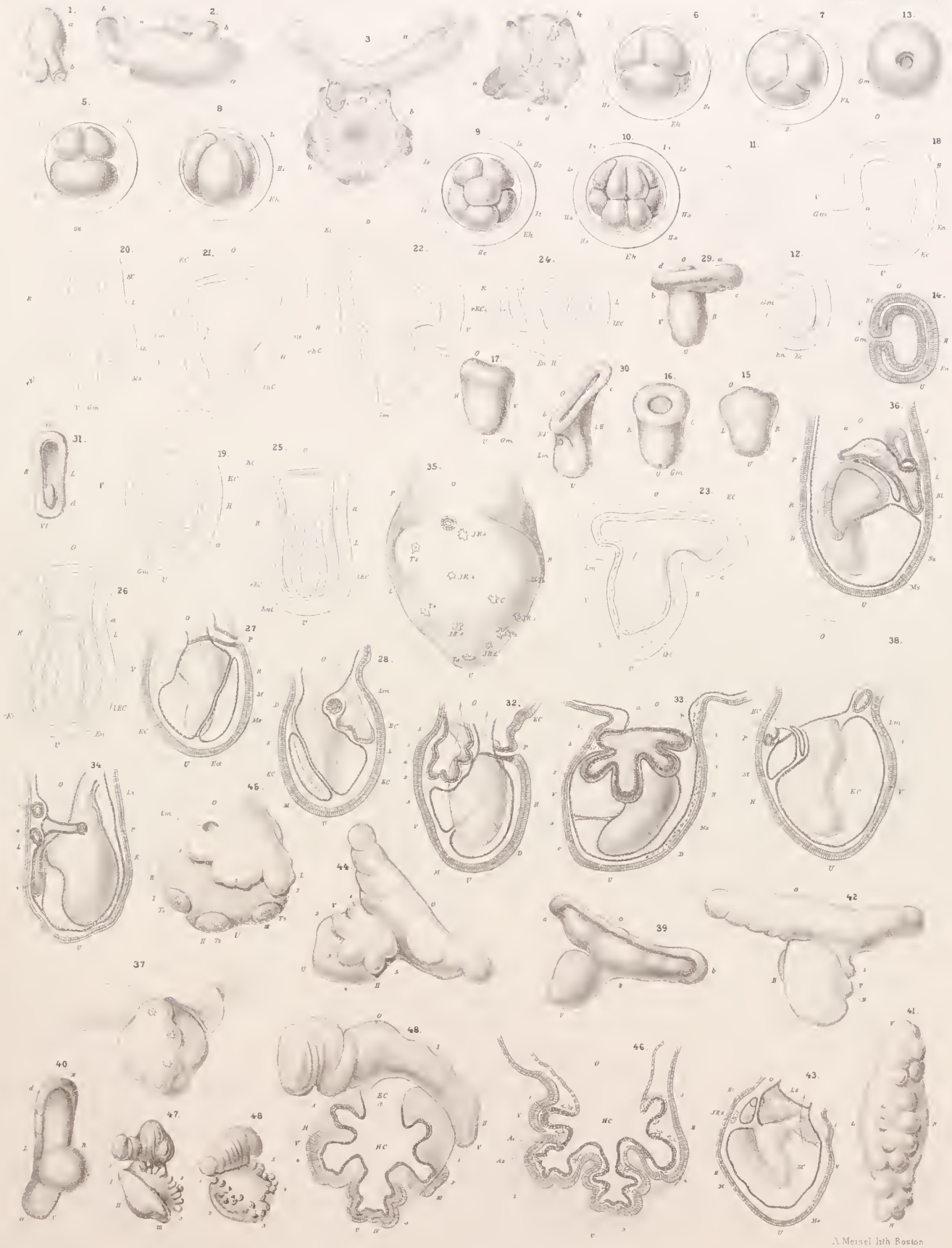

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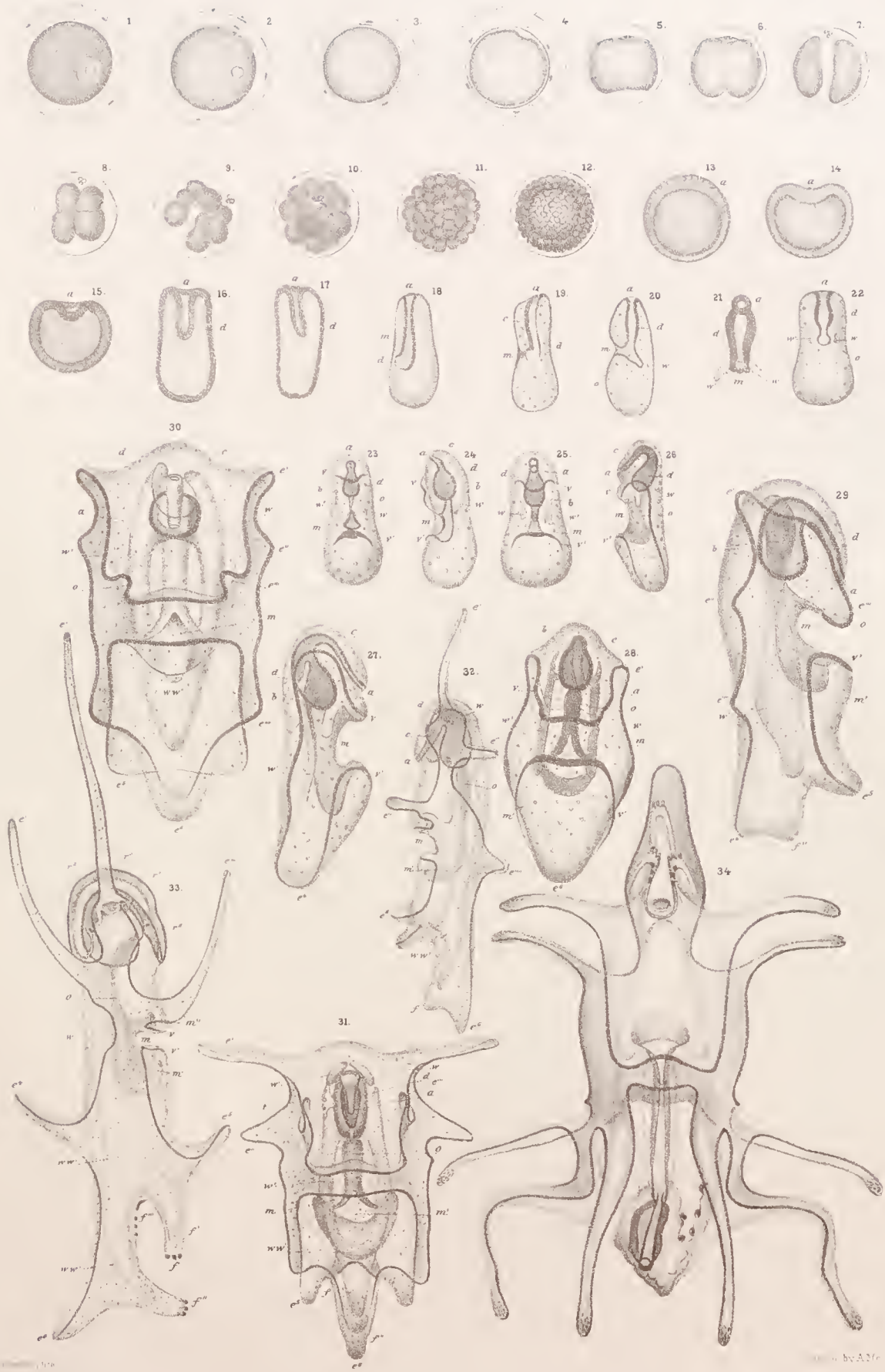
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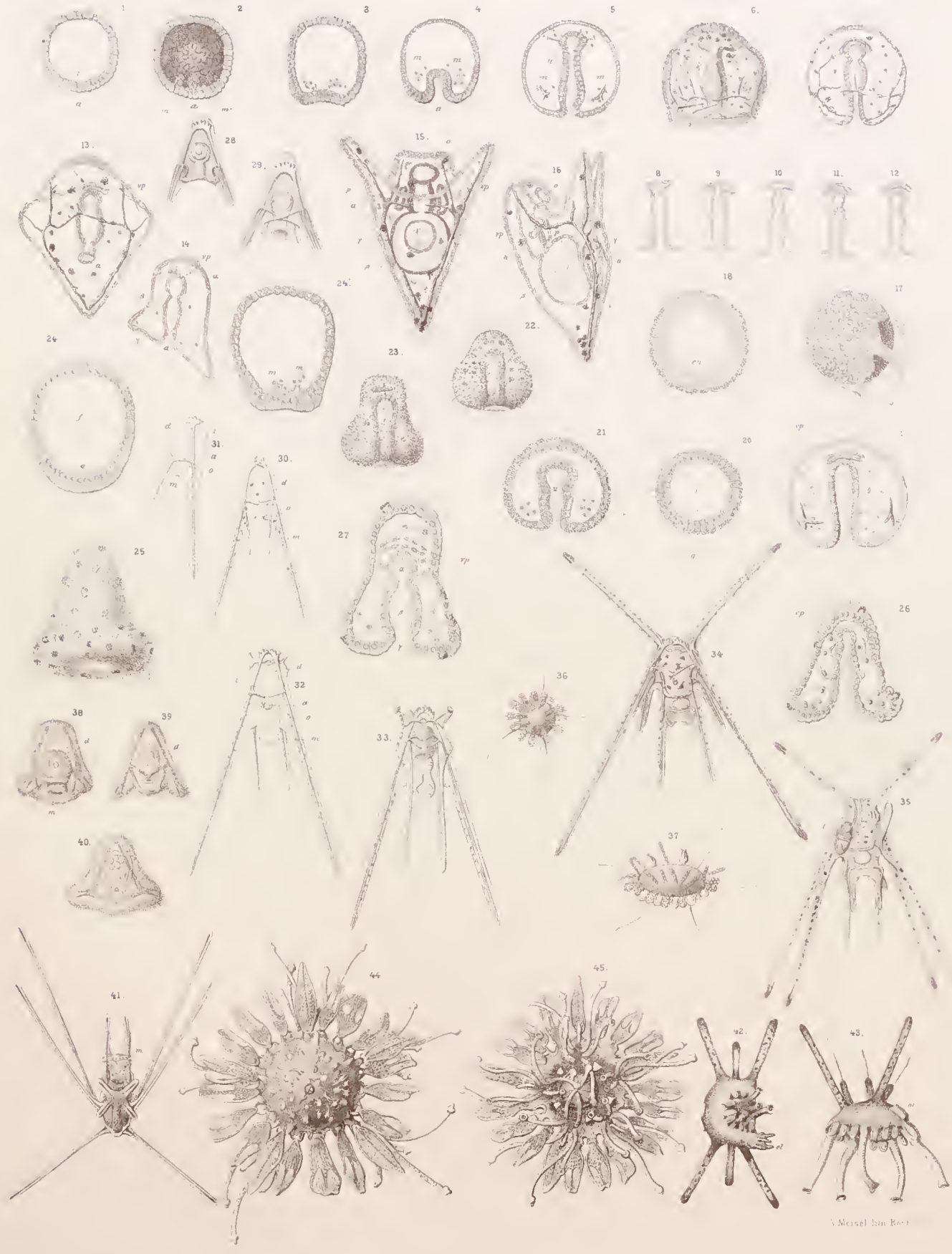
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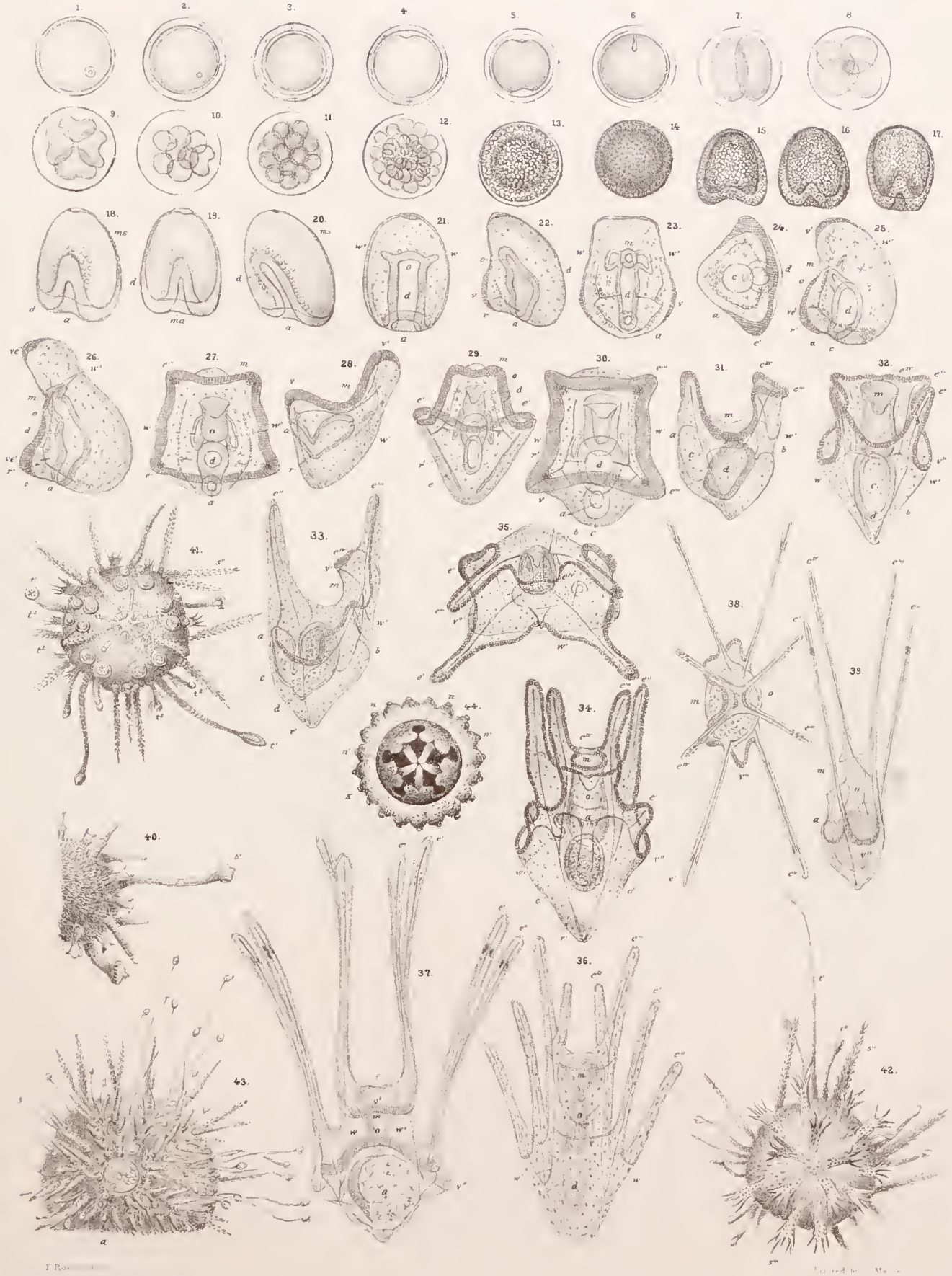
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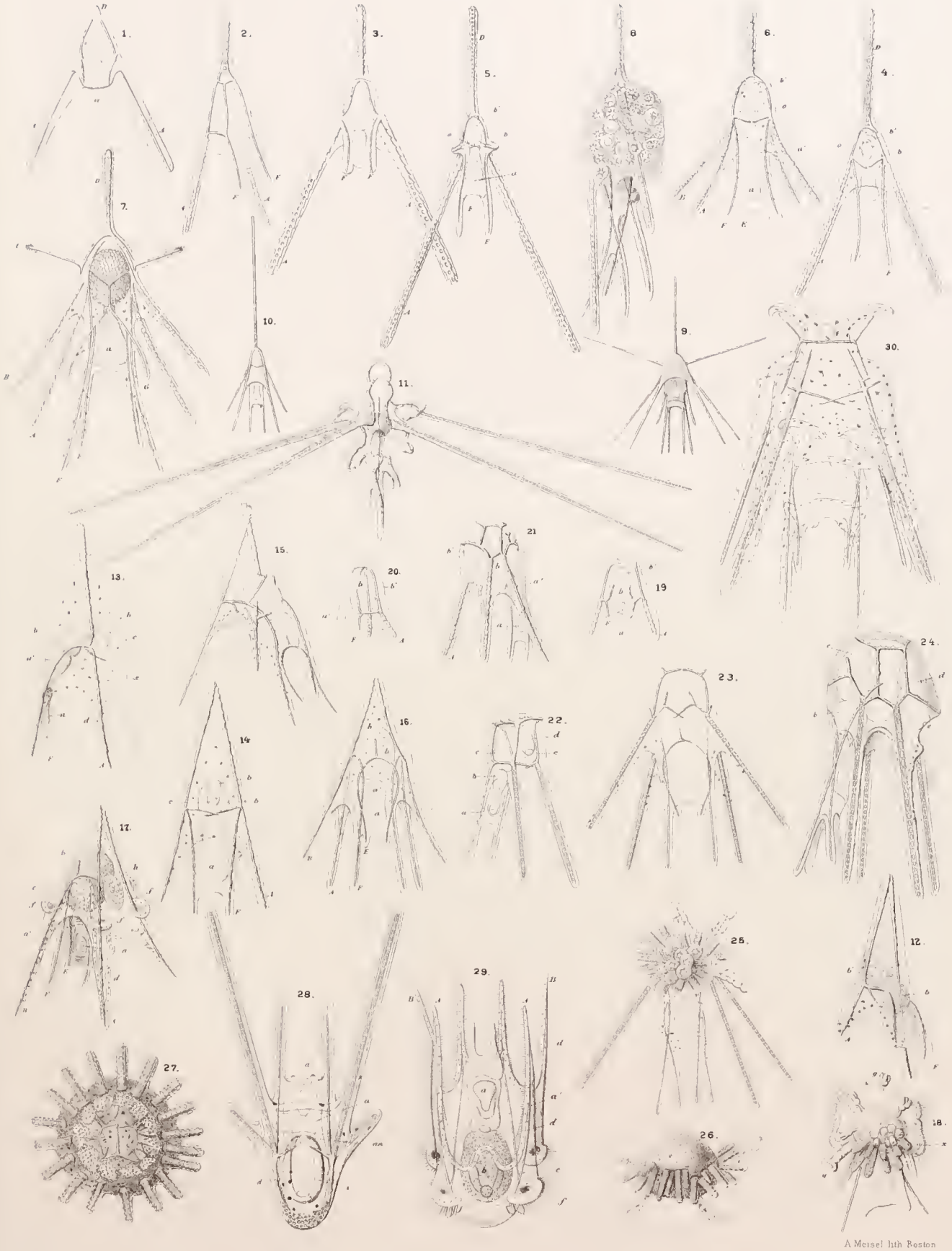

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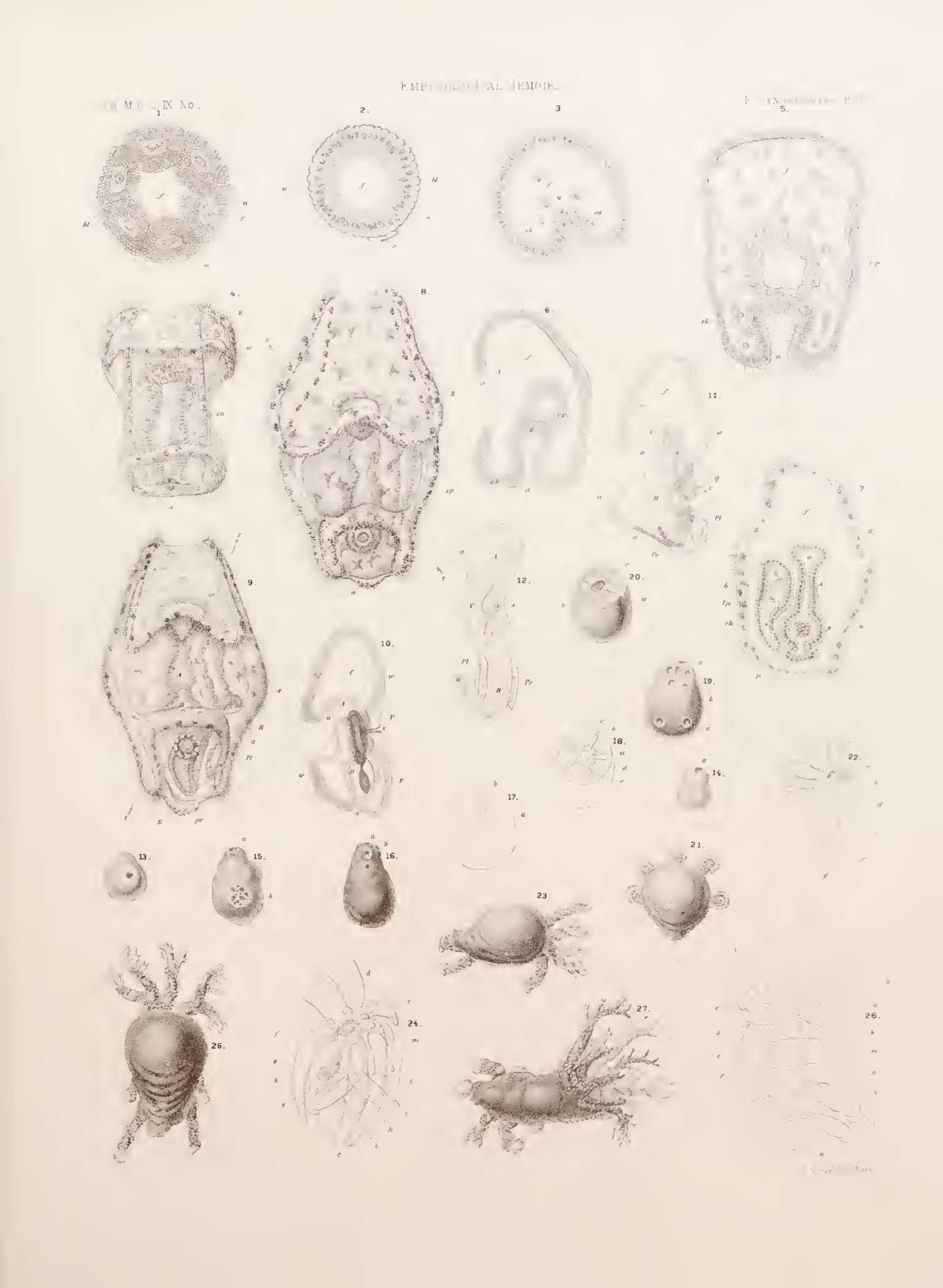
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